ILLUMINATING ENGINEERING

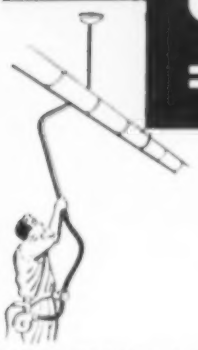
APRIL 1953

Positioning Directionally Adjustable Luminaires
Dirt Accumulation in High Bay Luminaires
Industrial Lighting Systems Appraised
Methods in Projection Photometry
Physiology, Light and Vision
Room Index Determinations

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

Formula for optimum lighting efficiency:

Quality + Cleanability = the Wakefield STAR



Making Light Work of It with Wakefield Maintenance Equipment

By using this blower-type Wakefield maintenance equipment, the janitor can keep Stars clean by spending five minutes a day once every three weeks in each room. For yearly washing of reflectors, lamps and channels, the janitor removes the reflectors (they slide in and out like a drawer) and uses an ordinary detergent.

Note: the Wakefield maintenance equipment shown is available free to purchasers of Stars in specified quantities. We will gladly give you details.

There are good reasons why the Star is recognized as a superior classroom luminaire and why it is so often recommended for "Co-ordinated Classrooms" (as well as offices, drafting rooms and other areas where critical seeing tasks are performed).

QUALITY OF LIGHT. Luminous Plaskon reflector sends most of the light to the ceiling, to be distributed evenly all over the room. Result: a minimum of reflected glare. The reflector, which completely hides the lamps, has about the same brightness as the ceiling. Result: a minimum of direct glare.

CLEANABILITY. The Star is one of the most easily and completely cleanable of luminaires. See column at left.

RECENT TESTS of actual installations, using the interflection method, indicate fewer Stars are required to light a room at a given level than had previously been thought necessary. We will be glad to send you the new coefficient of utilization tables.

The Star is equipped for pre-heat and rapid-start bipin and slimline lamps. See Sweet's architectural file. Or write to The F. W. Wakefield Brass Company, Vermilion, Ohio.

Pierce School
West Newton, Mass.
Room size: 23' x 36'
2 rows of four 4' units
2-75 W standard warm white fluorescent lamps per unit.
Footcandles: 32 average.

Wakefield Over-ALL Lighting

THE GRENADIER

THE PACEMAKER

THE COMMODORE

THE STAR

THE WAKEFIELD CEILING

Stop lamp replacement guesswork with the new Westinghouse slimline *lead-lag* ballast

. . . *the only ballast of its kind*

You *always* know which lamp is burned out in a 2-lamp fixture, *if your ballast is lead-lag.* In case of a burnout, you lose only the light from one lamp, because lamps operate independently in a *lead-lag* circuit. So why not take advantage of this maintenance economy and insist on the new, Westinghouse *lead-lag* ballast?

Lead-lag has always given this prime advantage, and a lot more, but never before at today's low prices and new small sizes. Prove for yourself these further savings in trouble and money:

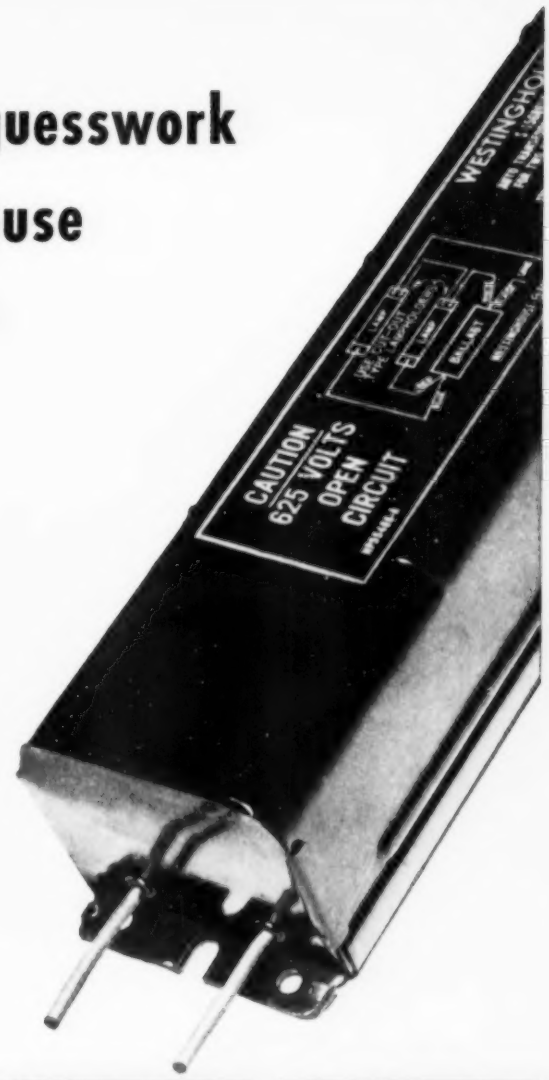
1 No more dangerous "stop-go" illusion. Stroboscopic correction helps prevent machine accidents . . . permits use in any industrial and commercial application.

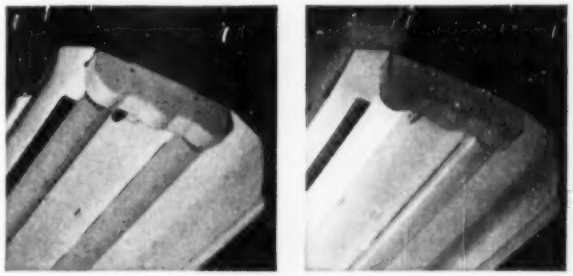
2 Maximum lamp life. Tests prove up to 10% longer life than with any other type ballast.

3 Low installation costs because of simple wiring, light weight and small sizes in the new Westinghouse *lead-lag* ballast.

4 Minimum heat to be dissipated by the fixture, because of the low wattage loss in the new Westinghouse design.

It's economical and practical to insist on Westinghouse *lead-lag* ballasts in any fixture you buy—or to replace old, less efficient ballasts. The Westinghouse ballast is available in both slimline and preheat fluorescent lamps. Get all the details in booklet B-5614, Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. Or phone your nearest Westinghouse office today. J-04345





Only one lamp has burned out in each fixture. Yet, with a series ballast, as shown in photo "A", both lamps are out. With a *lead-lag* ballast, you know which lamp has burned out—and you do not lose the light of the other good lamp—as shown in photo "B".

YOU CAN BE SURE...IF IT'S
Westinghouse

...We tripped the LIGHT fantastic...

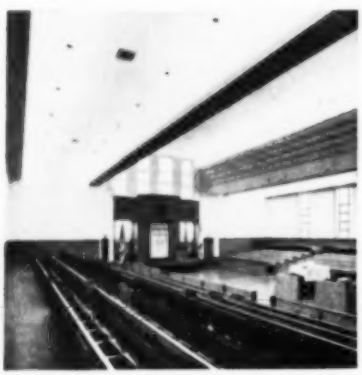
at the 1953 NATIONAL TECHNICAL CONFERENCE of the I.E.S.

•

NEW YORK CITY

HOTEL COMMODORE

SEPT. 14-17



Plan Now For

- Technical sessions on the elements of modern lighting.
- Visits to New York's spectacular lighting installations.
- Personal contact with key men in the lighting industry.
- Enjoyment of New York's entertainment fullness—theaters, sports, music, art, industry and architecture.

ILLUMINATING ENGINEERING

THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

APRIL
1953

Vol. XLVIII

No. 4

Skilful Use of Lighting Helps Convert Factory Area to Display Rooms at Low Cost ... 173

Positioning of Directionally Adjustable Luminaires — Merle E. Keck ... 175

Planned Lighting Permeates Pittsburgh ... 182

Practical Reduction of Dirt Accumulation in High Wattage Luminaires — J. W. Steiner ... 184

I.E.S. Lighting Data Sheet — Series XVIII
Lighting a Dental Office (18-9) ... 187

The Use of Zonal Constants in the Calculation of Beam Flux from Candlepower Distribution Data — T. H. Projector ... 189

Versatile Goniometer for Projection Photometry — T. H. Projector ... 192

An Appraisal of Illumination Calculations for Luminous Indirect Luminaires — R. D. Burnham ... 197

I.E.S. Lighting Data Sheet — Series XVIII
Lighting a Zoo Bird Cage (19-15) ... 201

New Formula for Room Index — C. L. Crouch and Eve Freyer ... 203

Numerical Room Ratios — Willard Allphin ... 206

Are We Confusing "Eyes" with "Vision"? — Darell Boyd Harmon ... 209

Cost and Comfort Appraisal of Industrial Lighting Systems — G. J. Taylor and R. D. Bradley ... 213

Also: Mercury Vapor Street Lighting on College Campus, 174; High Level Illumination in Hospital Delivery Room, 186; Louverall Lighting in Hospital Lobby, 196; Unusual Ceiling Technique in Clothing Store, 230.

I.E.S. National Technical Conference ... 2A

TELECAST — Lighting News of Current Interest ... 5A
Here and There with I.E.S. Members, 6A; Lighting Calendar, 7A; It Seems to Me, 12A; Obituary, 15A; About People, 15A; Books and Pamphlets, 28A; New Members, 32A.

Illuminating Engineering Society ... 16A

I.E.S. Publications ... 25A, 26A

Index to Advertisers ... 36A

I.E.S. National and Local Officers — Refer to March 1953 issue of ILLUMINATING ENGINEERING.

I.E.S. Committee Personnel — Refer to March 1953 issue of ILLUMINATING ENGINEERING.

Sustaining Members — Refer to February 1953 issue of ILLUMINATING ENGINEERING.

1952-1953 Officers

E. M. Strong — President

A. H. Manwaring — Vice-President

Duncan M. Jones — Vice-President

Clarence C. Keller — General Secretary

Kirk M. Reid — Treasurer

Staff

Ruby Redford — Editor

Clayton E. Ellis — Advertising Manager

Publications Committee

Duncan M. Jones, Chairman

J. S. Schuchert

R. M. Zabel

STATEMENTS and opinions in articles and papers in ILLUMINATING ENGINEERING are the expressions of contributors and do not necessarily represent the policies or opinions of the Society. Official Society opinions are expressed only in official committee reports specifically approved by the Council of the Illuminating Engineering Society.

Founded 1906

ILLUMINATING ENGINEERING SOCIETY

A. D. Hinckley, Executive Secretary

C. L. Crouch, Technical Director

PUBLICATION office 32d Street & Elm Avenue, Baltimore 11, Md.

EDITORIAL and advertising offices 1860 Broadway, New York 23, N. Y.

ILLUMINATING ENGINEERING: The Journal of the Illuminating Engineering Society. Copyright 1953 by the Illuminating Engineering Society. Published monthly in the United States of America. Entered as second-class matter at the Post Office, Baltimore, Md. Acceptance for mailing at special postage rates provided for in Section 1103 P.L.&R., Act of October 3, 1917. Authorized July 16, 1918. ¶ Subscription $10 per year plus extra postage to all countries to which second-class postage rates do not apply; single copies $1.50. ¶ Address changes must be received at I.E.S. headquarters by the first of the month to be effective with the issue of the next succeeding month.

NEW

"PRINCESS" 5000 SERIES

LUMINOUS INDIRECT FLUORESCENT LUMINAIRES

- **APPROPRIATE BRIGHTNESS CONTROL**
  . . . quality lighting with comfortable brightness ratios providing . . .
- **EYE COMFORT**
  . . . in seeing by scientific shielding, diffusing and distribution of the lamp light through . . .
- **LOW BRIGHTNESS**
  . . . illumination that gives you lighting comparable to diffused daylight.

• The new Curtis "Princess" luminous indirect 5000 Series luminaires have Curtis quality construction and workmanship throughout . . . with wire channel constructed of heavy gauge steel finished baked white "Fluracite" enamel. Side panels are fine ribbed durable polystyrene plastic to softly diffuse the light and provide low-brightness ratios between the ceiling and luminaire. Curtis 5000 Series luminaires are available to accommodate all 4', 5' and 8' fluorescent lamps. Send coupon for complete descriptive information.

CURTIS
LIGHTING, INC.

CURTIS LIGHTING, INC.
Dept. D41-19, 6135 West 65th Street
Chicago 38, Illinois

Name_____

Company_____

Address_____

City_____ State_____

Same area — before and after.

Skilful Use of Lighting Helps Convert

Factory Area to Display Rooms at Low Cost

WHEN the Kane Company, a Cleveland distributor of electrical appliances and furniture, remodeled a former mill building as their new headquarters, the architect made lighting a major factor in the transformation of the former factory space into display areas. The lighting system was designed with the thought that the light sources should be as inconspicuous as possible and yet be used to blind out the existing rough structure and eliminate the need for a completely new finished ceiling. The accompanying illustrations show how well these two somewhat conflicting goals were reconciled and attained.

Display areas are found on both the third and fourth floors of the building. Television sets, radios, kitchen equipment, and electrical appliances are shown on the third, while the fourth is devoted to furniture. On both of these floors, the ceiling consists of 6 by 16-inch joists, 30 inches on centers, supporting the floor above. The joists rest on 12 by 16-inch beams, in turn supported by wooden columns which divide the area into 16 by 20-foot bays.

To light the third floor, every other space between joists is used as a ready-made troffer. The joists and ceiling have been spray painted a flat, warm off-white, and a continuous row of single lamp 96T12 slimline fixtures is mounted in every other space. The deep joists act as excellent shields, and the overall continuity of the installation gives the impression that the ceiling itself it the light source. Extra wiring has been provided in the fluorescent channels to facilitate the mounting of filament spotlights at any point. The fluorescent installation provides a general illumination of 40 footcandles.

For the fourth floor, where the furniture displays are located, filament lighting was chosen because of the desire for a home-like atmosphere and because the lights are switched on and off frequently. In this area, the joists and ceiling have been painted

Foreground display shows movable shelves allowing for flexibility, in second floor appliance display room.

Stepped metal luminaires on 4-foot square plywood are used in third floor furniture showroom.

a flat black, and four by four-foot sections of plywood, painted white, are mounted directly on the bottoms of the joists on nine-foot centers. A concentric ring luminaire, housing a silvered bowl lamp, is suspended from the center of each white plywood panel. The general lighting level resulting from this installation is approximately 15 footcandles, while floor lamps on display in this area add enough light to bring the average illumination to from 20 to 25 footcandles.

In addition to the influence of these lighting techniques on the appearance of the Kane Building interiors and in addition to their economy, the simplicity of the luminaires and their easy accessibility facilitates lamp replacement and offers few surfaces for the collection of light absorbing dust. Maintenance of the lighting installation in this building should not be difficult.

Architect for this project was Michael M. Kane, Cleveland Heights, Ohio. The material and photographs for this article were furnished by Mr. Kane.

Mercury Vapor Street Lighting on College Campus

The objective of this campus lighting installation at Millsaps College, Jackson, Miss. (enrollment, 450 students), was to provide adequate illumination on sidewalks and driveways and enough light for easy visibility over the main campus grounds. Thirty-eight luminaires, equipped with 16,000-lumen mercury vapor lamps, were mounted on 25-foot steel poles, spaced approximately 125 feet in a staggered arrangement along the sidewalks and driveways. Multiple service was supplied by underground feeders. Illumination level along sidewalks and driveways averages .8 footcandles, with considerably higher amounts at campus and building entrances. Photo and data supplied by H. S. Thomas, Mississippi Power & Light Co., Jackson, Miss.

Positioning of Directionally Adjustable Luminaires

By MERLE E. KECK

ILLUMINATING engineers are using directionally adjustable luminaires to solve more and more of today's lighting problems. By a directionally adjustable luminaire is meant a luminaire which may be oriented on the job so that the relative direction of its maximum candlepower may be varied with regard to the plane in which it is mounted or in regard to the plane of the surface or objects to be lighted. A listing of some of the types of directionally adjustable luminaires would include:

1. Concealed downlights.
2. Reflector lamps in their variety of gimbal rings and swivel hangers.
3. Industrial concentrators.
4. Conventional type floodlights.
5. Searchlights.

Illuminating engineers have found that it is relatively simple to compute the effect of directing one such luminaire at an object or plane surface. Such calculations are normally made by using the point by point method of calculation. However, when it is desired to compute the combined effects of a number of such luminaires, located at approximately the same point or at different points, and directed at an area larger than can be covered with one luminaire; the point by point method of calculation becomes too tedious for normal usage. As an example, consider the floodlighting of a baseball field with a hundred or so luminaires which must be directed so as to produce uniform horizontal footcandles over the entire area. Or take the case of a building to be lighted with a bank of 30 units where the designer wishes the illumination to taper gradually from one intensity to a much lower intensity across the surface. In such cases as these the large number of units contributing light to any one point makes the predetermination of results by the point by point method much too laborious to be desirable.

Published literature gives no answers as to how to predetermine the effects that will be achieved by combining a number of directionally adjustable luminaires nor how to position such luminaires to produce a certain desired result. The published photometric data for such luminaires (if any are available at all) is not presented in a manner to simplify the task. The result is that such installations are often designed on the basis of guesswork and experience combined in the relative proportions of how much alike this particular job is to one the designer has previously done. It is the purpose of this paper to outline a method of determining the correct positioning of directionally adjustable luminaires so as to produce the desired illumination results when such results must be obtained by overlapping the photometric patterns of such luminaires.

Directionally adjustable luminaires may be divided into two large classes; those with symmetrical distributions and those with asymmetric distributions. Examples of the former include the majority of floodlights, reflectorized lamps, downlights, spotlights and searchlights. Examples of the latter include cylindrical fresnel floodlights, streetlighting units mounted on adjustable brackets, and certain types of floodlights. The material contained herein deals chiefly with symmetrical distributions, but is applicable to certain asymmetrical distributions.

Principles of Light Pattern Formation

A luminaire with perfectly symmetrical distribution emits its light in the form of a cone with the surface of the cone generated by rays of equal candlepower. The pattern produced on any opaque flat surface will be formed in accordance with the laws of geometry of a plane intersecting a cone. The two common patterns, a circle and an ellipse, formed by a plane surface intersecting a cone are shown in Fig. 1. Since the lumens generated by the luminaire are distributed in the conical beam in a definite fixed manner the distribution of light on the plane surface intercepting that beam will vary according to the angle of interception, called directional angle hereafter. With a symmetrical distribution (symmetrical about the axis of the cone) this change in distribution on the plane surface will be a function of the directional angle (angle between luminaire axis and the plane of the surface to be lighted) as shown in Fig. 1.

A graphical representation of the variation in footcandle intensities on a plane, measured parallel

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Sept. 8-12, 1952, Chicago, Ill.
AUTHOR: Westinghouse Electric Corp., Cleveland, Ohio.

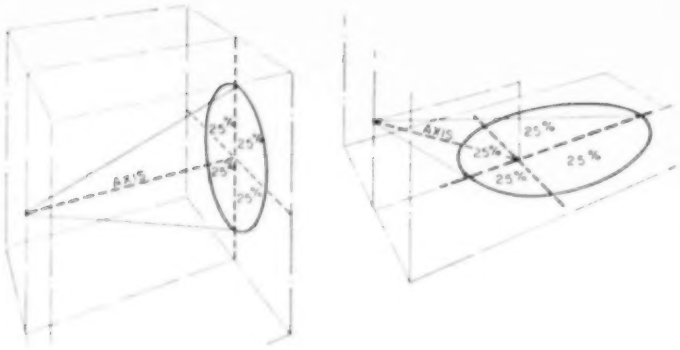


Figure 1. The photometric pattern as determined by a line of equal candlepower varies in accordance with the angle of the luminaire axis with the surface to be lighted. One result of this is that equal percentages of lumens produced must cover unequal areas of the pattern in many cases.

to the surface of that plane, over the pattern of a typical luminaire with symmetric distribution when directed with θ (directional angle) equal to 0°, 30° and 60° is shown in Fig. 2. Since the prediction of illumination results must be based on the additive effects of several such patterns superimposed one upon the other, it is essential that we have the photometric data presented in a manner that permits easy determination of the amount of illumination at any point regardless of the directional angle. Any particular point can be located or described by its locational angle which is the angle between a line connecting that point to the luminaire and a line normal to the surface being lighted as indicated in Fig. 2. Such a presentation of photometric data for any point along the longitudinal axis of the photometric pattern and for any directional angle are shown for two typical luminaires in Figs. 3 and 4. These curves indicate the percentage of the maximum footcandles which will occur at any point, designated by its locational angle x and, for any direction angle θ. The luminaires for which these data have been presented are the 75-watt PAR-38 projector flood and projector spot lamps. They were chosen since their physical size and maximum candlepower are small enough to permit relatively small laboratory set-ups to check for accuracy. These curves do not indicate either the relative value or the exact value of maximum footcandles for one directional angle as compared to another. Such relative values are shown in Fig. 5. Thus from the combined use of Fig. 3 or 4 and Fig. 5 (product of the two percentage values) it is possible to determine the relative intensity at any location on the longitudinal axis of the pattern for any directional angle. In addition the specific footcandle level at any point may be found by referring all locations back to the maximum intensity that would occur at θ equal 0° if the maximum candlepower of the luminaire is known.

From the curves of Figs. 3, 4 and 5 it is possible to predict the results of pattern overlap along the longitudinal axis of the patterns produced. It is also necessary to predict the results from the overlap of the patterns along the lateral axis of the light patterns. The author generally uses the con-

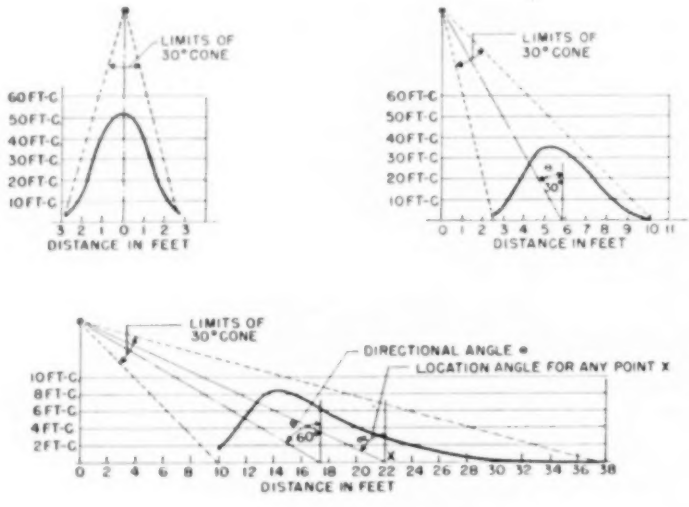


Figure 2. Actual footcandle intensities and distribution vary widely as a directionally adjustable luminaire is positioned at different directional angles. The height above the work plane is constant for angles of 0°, 30° and 60°.

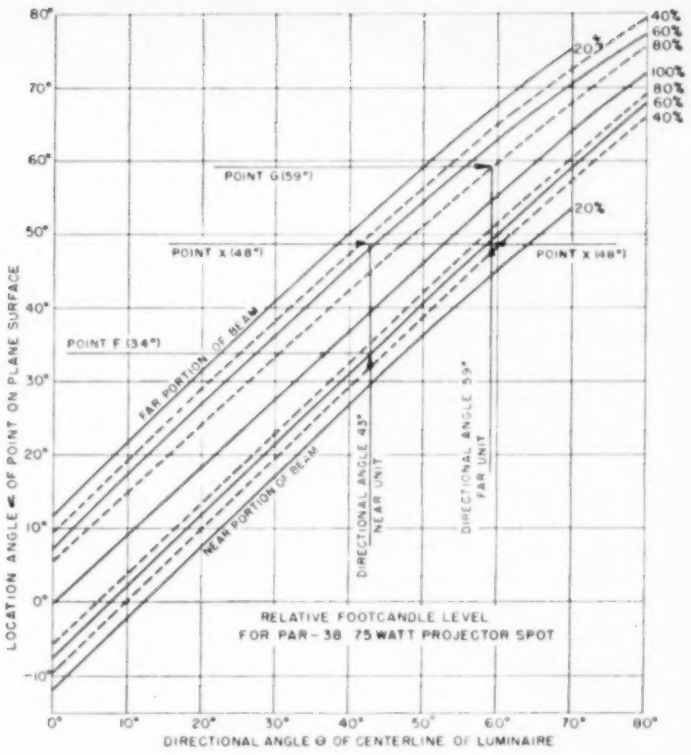


Figure 3. Photometric data for 75-watt PAR-38 Projector Spot Lamps presented in a manner to permit quick determination of the relative footcandle level at any point for any directional angle of adjustment.

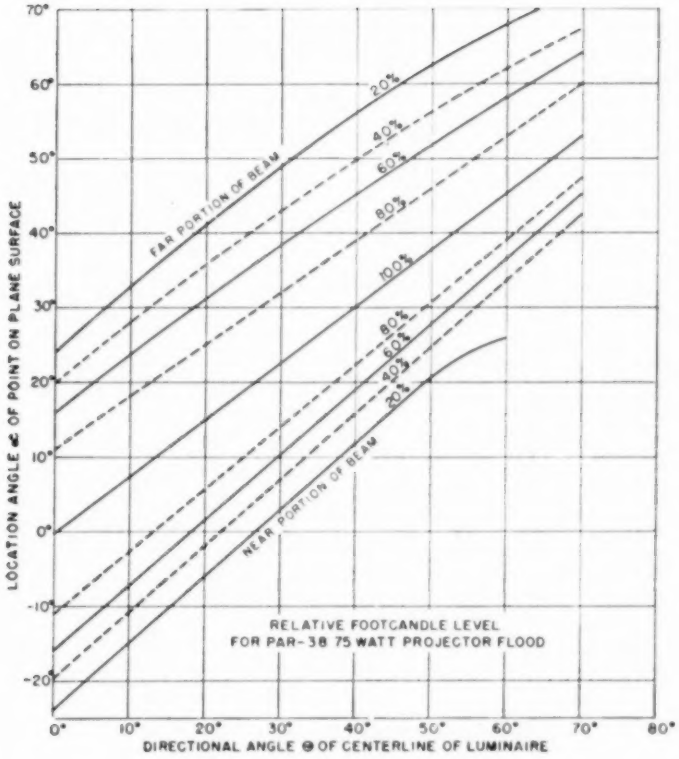


Figure 4. Photometric data for 75-watt PAR-38 Projector Flood Lamp presented in a manner to permit quick determination of the relative footcandle level at any point for any directional angle of adjustment.

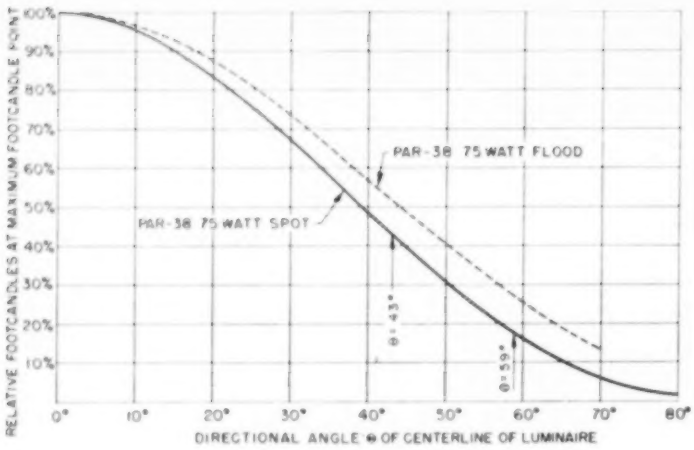


Figure 5. Variation in footcandle level, at the maximum footcandle point, for any directional angle of adjustment.

cept of circular positioning paths for lateral overlap of patterns, as shown in Fig. 6, and the lateral overlap for such calculations can be made from curves such as the one shown in Fig. 7. The curve in Fig. 7 indicates the relative intensity resulting from any spacing along a circular path around the point where they are located.

Since the relative intensity resulting from any particular spacing will be the result of the additive effect of the candlepower from adjacent units and since this additive effect will depend on angle β' (Fig. 6) rather than the angle β which is the lateral spacing angle for the circular path of aim it is essential to correct for this variation when using the curve of Fig. 7. The curve in Fig. 7 is made for the theoretical condition of directional angle θ equal 90° in which case the angle β and β' of Fig. 6 would be equal. Since the relationship between angle β' and angle β is a simple one and depends only on the directional angle θ a simple correction can be made. Hence to find the relative

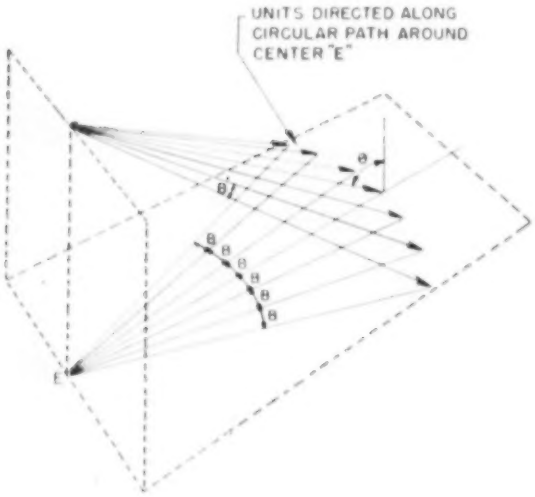


Figure 6. Units directed around a circular path permit a simple determination of the relative intensity for any lateral spacing angle β.

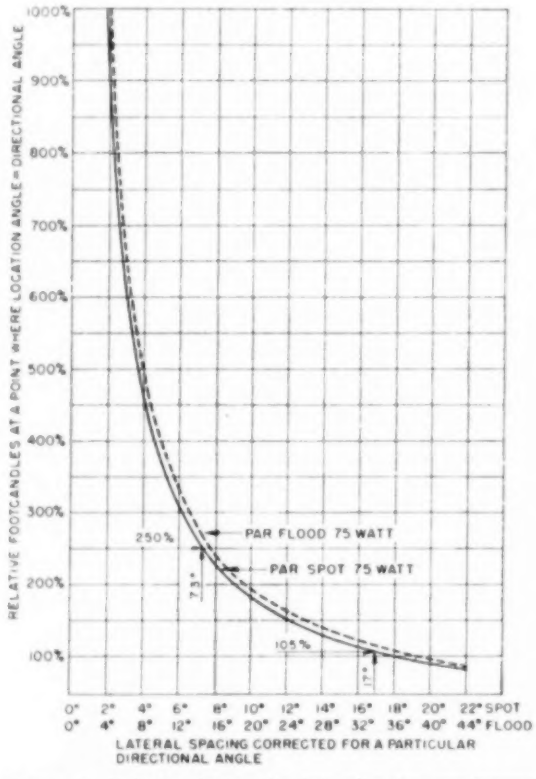


Figure 7. Relative footcandle intensity for any lateral spacing, along a circular positioning path, as compared to the intensity of one unit. Lateral spacing for a particular directional angle must be corrected to the equivalent spacing at directional angle of 90° before usage.

intensity for a particular lateral spacing at a particular directional angle (θ) it is necessary to multiply the given lateral spacing by the sine of θ to determine the equivalent spacing for θ equal to 90°. This equivalent spacing can then be used to find the relative intensity for the given spacing at directional angle θ. The reverse of this must be used in determining a particular spacing to produce a certain intensity.

Application to a Specific Problem

Perhaps the best way to explain the usage of the the photometric data presented in this manner is to follow step by step a sample problem. Let us assume that we have an area *ABCD* which is six feet by six feet and which is to be lighted uniformly from a location which is four feet below and six feet in front of the area to be lighted. The maximum footcandle level is to be 60 footcandles and the ratio of maximum to minimum footcandles should not exceed a 2:1 ratio. This area as well as the solution to the problem is shown in Fig. 8. The problem would be attacked in this manner.

1. Determine the location angle of points *F* and *G*. Location angle of point *F* is $\tan^{-1} 4/6 = 34°$. Location angle of point *G* is $\tan^{-1} 10/6 = 59°$.
2. If we assume the footcandle level at point *F* (34°) is to be 60 per cent of the maximum footcandles, then from the curve in Fig. 3 we can determine that a unit must be directed at $\theta = 43°$ to produce the 60 per cent at point *F* and further it can be determined that the intensity from this unit will decrease to 50 per cent of the maximum at point *X* with a locational angle of 48°. Now to overlap this point with another pattern having an intensity of 50 per cent at point *X* (48°) will require the second unit to have a directional angle of 59° (this information is also taken from the curve in Fig. 3) and will produce an intensity of 80 per cent of its maximum at point *G* (59°).
3. Having determined that it is necessary to use luminaires positioned with directional angles of 43° and 59° respectively, it is now necessary to ascertain what lateral spacing is required to provide a maximum intensity of 60 footcandles. From the curve in Fig. 5 we find that one unit with directional angle of 43° will produce a maximum intensity of 43 per cent of the maximum that would be achieved if the directional angle were 0°. Since the unit we are dealing with is the 75-watt PAR-38 projector spot lamp and its rated maximum candlepower is 4800, the footcandle intensity at a directional angle of 0° and a distance of 6 feet would be (ft-c = $CP/D^2 = 4800/36$) 133 footcandles. Thus from the unit directed at 43° the maximum intensity in footcandles would be $133 \times 43\% = 57$ footcandles. Since we desire a maximum of 60 footcandles the lateral spacing must be such as to provide 60/57 or 1.05 times that intensity (105 per cent). Similarly for the unit directed at 59° the maximum intensity will be 18 per cent of the intensity at 0° or 24 footcandles and, to achieve 60 footcandles, it will be necessary to provide a lateral spacing to produce 250 per cent of that produced by the one unit. The correct lateral spacing angle is found from the curve in Fig. 7 as follows.

   From the curve of Fig. 7 we can find that to produce a relative footcandle level of 250 per cent with the PAR spot requires a spacing of 7.3° but this is for the theoretical condition of $\theta = 90°$ and for the special case of $\theta = 59°$ the spacing would be 7.3° divided by Sin 59° which is equal to

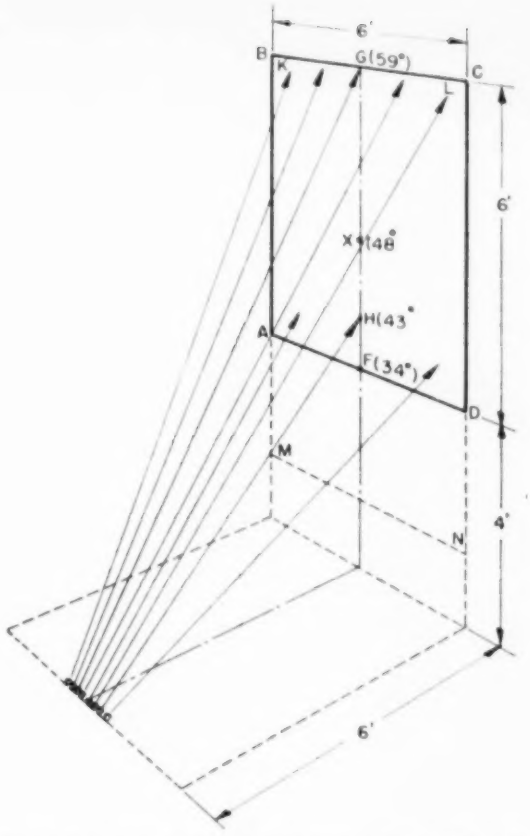


Figure 8. Example problem with area to be lighted indicated by *ABCD* and final positioning diagram as determined from curves shown.

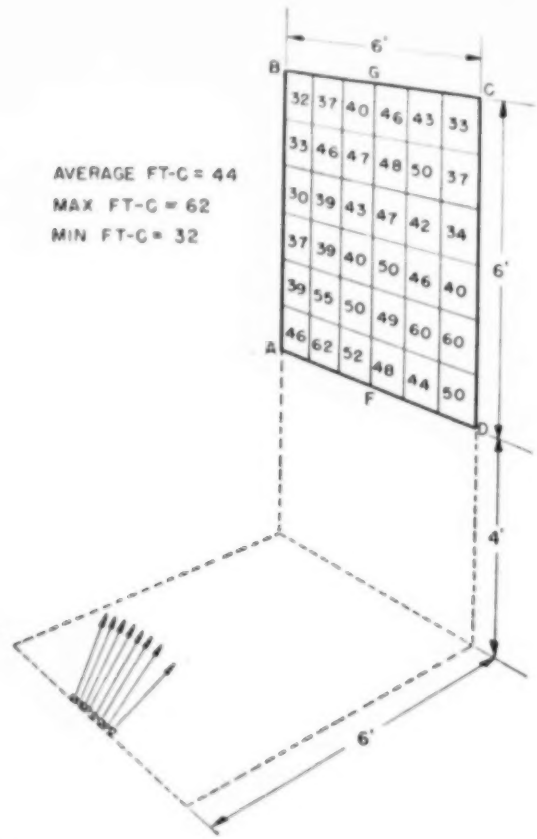


Figure 9. Diagramatic representation of example problem showing measured footcandle results from full scale model.

8.5°. Similarly the corrected spacing for the units at 43° which must produce 105 per cent relative footcandle level is 25°.

4. The final step is to transfer these angular computations into a positioning diagram such as that in Fig. 8. Here we see that three units spaced at 25° are needed on the inner circle ($\theta = 43°$) and 5 units spaced at 8.5° are needed for the outer circle ($\theta = 59°$).

The above determination of a positioning diagram illustrates one application of the photometric data as presented. However, it must be remembered that the lateral spacing chart is based on the assumption that units are spaced along the circular path around its entire circle of 360°. In the case where a definite area is to be lighted as in the example above, such is not the case. The arc of each of the concentric circles is limited and hence we can expect that this lateral spacing as chosen will not permit a build-up to the maximum intensity indicated by the curves in Fig. 7. This should be more pronounced in the area between point *X* and *G* than in the area between points *X* and *F*.

This example was, along with other portions of the calculated data, checked by setting up in the laboratory full scale models using 75-watt PAR-38 projector lamps for which the curves in Fig. 3, 4, 5 and 7 were calculated. The diagramatic representation showing the measured data is shown in Fig. 9. As can be seen, the results barely meet the basic qualification of a 2:1 variation in footcandle level. This can be attributed almost entirely to the fact that in the upper arc of the positioning points where the intensity must be built up to 250 per cent of that of one unit alone, the intensities are low and fall off excessively at the right and left edge of the area. This can be corrected by directing one additional unit at points *K* and *L* (Fig. 8) respectively and led to the formulation of the following basic rule. *Where the lateral spacing must increase the intensity to over 200 per cent of that produced by one unit, then a correction must be made at the termination of the ends of the arc. This correction to consist of one additional unit directed at the terminal positioning point for each 200 per cent of build-up required.* There also will exist certain variations between the average photometric data used in the calculation of the curves and the actual photometric performance of each particular unit. Such manufacturing tolerances are to be expected and exactly perfect agreement between the calculated level at a point and the measured level almost never exists.

This type of solution can utilize more than one type of luminaire. For example if it were desired to illuminate an additional three feet of space as indicated by the area *ADMN* (Fig. 7) the solution would have required three circular aiming paths, one of projector flood lamps and the other two of projector spot lamps. The data relative to the choice of spacing of the projector flood lamps would come from the curves in Figs. 4 and 7 and the problem would be worked out in the same manner as that in the previous example.

Conclusions

It is possible to determine, from the photometric data presented in this manner, how to provide deliberately non-uniform intensities as well as uniform intensities and to predict within reasonable limits the results to be obtained from units located at different points covering the same area. This method of approach does not yield accurate results as regards the average intensity over the area. Such calculations can be made with considerable accuracy using the method worked out by the author in a previous paper.[1] It, and all other accurate methods of calculating average illumination for directionally adjustable luminaires presupposes that the luminaires have been directionally ad-

justed and the calculation methods in themselves do not indicate in any manner how to adjust the units.

The type of curves shown in Figs. 3, 4, 5, and 7 are not available from any lighting equipment or lamp manufacturer. It is possible to prepare such curves from the published photometric data of most floodlighting equipment and it is possible to secure sufficient photometric data from the lamp companies to prepare such curves for the reflector lamps. The object of this paper is not to present a printed group of curves for any, or even a typical adjustable luminaire, but rather to present one engineering approach to the problem of how to position directionally adjustable luminaires. It is the author's opinion that the method outlined herein should be carefully examined by the Lighting Design Practice Committee and the Committee on Illumination Performance Characteristics so that a uniform method of presenting the necessary photometric data can be worked out.

Reference

1. Keck, M. E.: "Utilization Curves for Floodlights," ILLUMINATING ENGINEERING, Vol. XLV, No. 3 (March 1950).

DISCUSSION

R. D. BURNHAM*: It appears that Mr. Keck has made a substantial contribution to the field of floodlighting and its associated fields. I would like to reiterate Mr. Keck's statement that the proper committees investigate this system, and if it is as accurate and relatively simple as it appears, it deserves a place in our standard practice. There are a couple of questions which I would like to put to the author: first, with reference to a positioning path to accomplish lateral overlap, is this the procedure most generally followed in floodlighting design? Second, when the directional angle is large, with a small lateral overlap, is there not a danger of dark spots in the upper portion of the beam pattern?

The author set up a mock up and measured the previously calculated illumination level under laboratory conditions. Are data available on actual installations, comparing this method of calculation with measured values, or does the author intend to do this in the future?

R. T. DORSEY**: Mr. Keck has developed a promising method for aiming floodlights and spotlights. His charts present much point-by-point information in a form which greatly facilitates calculations.

The method permits the prediction of results along the axis of the beam pattern and on one arc described by the aiming points where units are grouped at one location and aimed radially. It does not show what the distribution will be along concentric areas — in fact a rough check indicates that the two-to-one stipulation will not be met along the lower portion of the area dealt with in the example.

Our analysis of the relation between β and β' indicates the expression should be $\beta' = 2 \sin^{-1} (\sin \theta \sin \beta/2)$ rather than $\beta' = \beta \sin \theta$. However, little difference will occur where angular spacing is small.

While the method, as presented, will be useful for many applications, more complete information would be desirable. For example, in some cases, with other than radial aiming patterns, diagonal distributions are needed.

M. E. KECK*: Mr. Burnham's comments are appreciated and the questions he raises are both pertinent and interesting. It is the author's opinion that a circular positioning path for lateral overlap is the most logical and most promising method of attack for any systematic solution. It is true that for any floodlight type there is a minimum permissible overlap below which one cannot go without suffering a loss in uniformity of illumination; however, the author has not experienced any particular difficulty from this at large directional angles.

Some data are available on actual installations; in fact the author developed the method for and has been using it for some time in planning the aiming for sports fields. Naturally the data available are restricted to such fields as the author could personally check the resultant level of illumination in detail with adequately corrected instruments. In addition, some of the earlier field checks were made before some refinements were made in the method and hence could not be considered as real field checks on the final method.

Mr. Dorsey's comment concerning the relationship of angle β to β' is quite correct and is one of which the author is aware. In practical usage of this method it was found that angles of β in excess of 30 degrees were practically never encountered and since the error in the simpler expression $\beta' = \beta \sin \theta$ was less than one-half degree for $\beta = 30$ degrees and $\theta = 45$ degrees, I have used the simpler, though approximate, relationship. The reason that no explanation of this approximation was included in the text was purely one of space limitation imposed by the Papers Committee. It was felt that a justification of the approximation would require at least one more illustration and a half page of copy. Although the direct statement, $\beta' = \beta \sin \theta$ is not made in the paper, I find, after rereading the short paragraph devoted to this relationship, that the statements could have been worded to bring out more clearly that the correction indicated gives only a close approximation of β'.

I am in full agreement with the comment, "while the method will be useful for many applications, more complete information would be desirable." I feel, however, that it would be asking a little too much to expect, in one short paper, a complete answer to the complex problem of how to position adjustable luminaires. This paper is intended to present one engineering approach to the problem, and, since it is the first approach of which I have knowledge, it is hardly to be expected that it would be a complete answer to all such application problems.

*The F. W. Wakefield Brass Company, Vermilion, Ohio.
**General Electric Co., Nela Park, Cleveland, Ohio.

*Author.

Jones and Laughlin Steel Corporation — "Scarfers" in this new scarfing area work efficiently and safely under 50 footcandles provided by a combination system using 3000-watt mercury vapor lamps and 1000-watt incandescent lamps. The lighting units are connected to the 440-volt, three-phase system through the necessary auxiliaries. The incandescent lighting provides color correction and a means of re-establishing lighting instantly in the event of an interruption of service.

In the University of Pittsburgh's new field house, 40 footcandles of maintained general illumination is provided by 120 units using 1000-watt filament lamps. Mounting heights of the luminaires vary from 35 feet at the sides to 50 feet at the center of the arena. When the basketball floor is assembled in the center of the field house, an additional 28 units are energized to bring the illumination level over the playing court area to 60 to 70 footcandles. The luminaires are installed on tandem brackets on disconnecting lowering hangers to permit servicing at the floor level.

Planned Lighting "permeates" many cities. Outstanding installations, engineered to recommended practice, turn up in contests all over the country. They appear as official I.E.S. Data Sheets in every subscription series. The extent of its application in Pittsburgh, for instance, might be reflected in the circumstance that about twenty installations from that area have been submitted this year to the I.E.S. Data Sheet Committee. On this and the facing page are shown four of these jobs, some of which may later be developed into official Data Sheets for subscription distribution.

P/L Permeates Pittsburgh

In this attractive conference room at the Fidelity Savings and Loan Company, cove lighting is provided by single fluorescent strips around the perimeter of a center ceiling cove. The two ceiling fixtures are 300-watt silver bowl lamps in porcelain enamel dome reflectors with concentric ring louvers. Average level of illumination on the table top is 35 footcandles. Installation planned by George P. McKinney, Architect, and Lucien T. Kight, lighting consultant, Duquesne Light Company.

In the working area of this Pittsburgh bank, 50 footcandles are provided by two-lamp fluorescent troffers in an architectural element and recessed 150-watt reflector lamps positioned over the teller positions. In the public area, 35 footcandles are provided by recessed 200-watt incandescent boxes with glass covers. The installation was planned by George P. McKinney, Architect.

Practical Reduction of Dirt Accumulation In High Wattage Luminaires

By J. W. STEINER

For high bay lighting, especially, a substantial part of the cost of light may be found in the cleaning of the lighting equipment. Herein are reported the results of tests on ventilated versus non-ventilated high bay luminaires in relation to dirt accumulation and the maintenance of adequate illlumination levels for longer periods without washing.

ENGINEERS strive continually to reduce the frequency with which a luminaire must be serviced in any fashion. For high bay industrial areas, and especially with the acceptance of the longer-life mercury vapor lamps a new emphasis is added to their problem, since the cleaning (rather than relamping) schedule becomes the determining factor in the maintenance cost.

Recognizing that luminaire ventilation offered a possibility for pronounced reduction of dirt accumulation in high-bay high-wattage luminaires, a list of objectives for a proposed redesign of this type of equipment was set up, to include the following elements:

(a) The design must sweep the entire reflecting surface with a smooth air flow to avoid spotty dirt accumulation.

(b) Construction must eliminate possibility of thin material areas often resulting in one piece spun reflectors of deep design.

(c) Design must not involve "punched out slots" for holes, which might result in mechanically weakened units.

(d) The air flow path must not approach lamp base and socket area where the chimneyed hot air can actually increase temperatures on critical parts.

(e) Overhang must be provided to prevent water or dust from dropping on the lamp through the ventilation ports.

Once a design was solidified, accomplishing all of the above aims, an in-service test was arranged to evaluate approximately the improvement in maintained light output as compared with equivalent unventilated luminaires. Mercury vapor and incandescent lamps were used (efficiency results quoted are averages of these two sources). Two test areas were selected (a) the pouring and melting bays of a foundry with considerable dirt and smoke in the air, and (b) a high bay above fixture assembly lines with relatively clean conditions.

The results of the first 1000 hours of operation are presented in the following analysis and figures and are strikingly illustrated by the unretouched photographs (Fig. 1) of two mercury vapor units after 1000 hours operation in a foundry. It should be carefully noted that only the effect of dirt accumulation is included and that normal lamp depreciation is included and that normal lamp depreciation due to blackening and other internal causes must also be taken into account. For example, current published data indicate the following for general service lamps:

Lamp Size	Approx. Initial Lumens	Approx. Mean Lumens
1500-w PS52	33,000	26,000 (78.8%)
1000-w PS52	21,800	18,000 (82.5%)
750-w PS52	15,800	13,700 (86.7%)
500-w PS40	9,900	8,800 (88.9%)
400-w E-H1	20,000	16,200 (81%)
400-w J-H1	18,000	14,200 (78.8%)

Analysis of Data

Fig. 2 illustrates the effect of dirt accumulation on overall efficiency. Integrating the area beneath each curve yields the following "mean" maintenance factor (dirt only) which would apply under the particular conditions of these curves and assuming luminaires are cleaned after every 1000 hours operation (normal lamp depreciation to be added).

Area	Mean Maintenance Factor (Dirt Only) Ventilated High Bay	Un-Ventilated High Bay
Assembly	92%	86%
Foundry	91%	80.5%

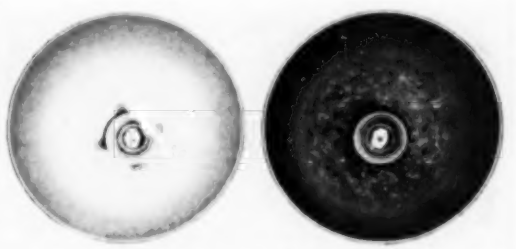
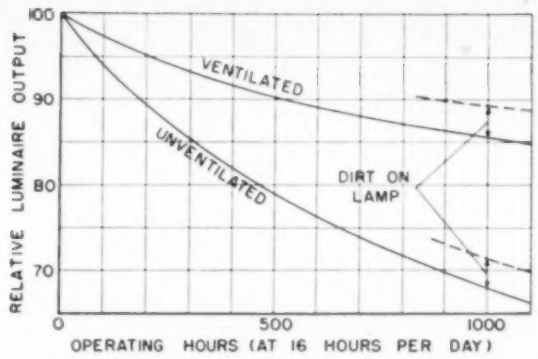
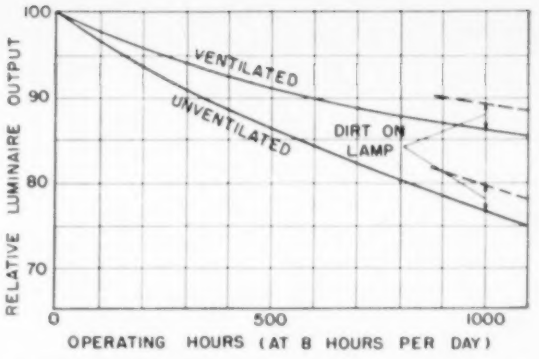


Figure 1. Ventilated (left) and unventilated (right) mercury vapor luminaires after 1000 hours operation in foundry.

AUTHOR: Engineering Section Manager, Westinghouse Electric Corp., Cleveland, Ohio.



A. Luminaires operated in pouring and melting area of iron foundry (dirty area).



B. Luminaires operated in high-bay area of fixture assembly plant (clean area).

Figure 2. Effect of dirt accumulation on overall efficiency. Depreciation due to lamp dirt is included. Blackening and other normal internal lamp depreciation is excluded and must be added.

If, on the other hand, luminaires were not washed for an extended period, it appears that the curves for ventilated high bay luminaires may approach a minimum asymptote at about 80 per cent including allowance for dirt on lamps. Note that in the case of the foundry area test, the lumen output of the ventilated luminaires even with no cleaning will evidently never fall below the mean output of unventilated luminaires washed every 1000 operating hours. An occasional dry wipe alone will apparently keep the ventilated luminaire mean output substantially above that of regularly washed unventilated luminaires. The curves for unventilated luminaires, however, can be expected to approach a low value around 50 per cent for the dirty area or 60 to 65 per cent for the clean area if left without maintenance for extended periods.

Fig. 3 shows the photometric distribution of a typical ventilated aluminum high bay unit taken initially and after 1000 hours of operation in the foundry area (16 hours operation per day). Fig. 4 shows similar curves for an unventilated luminaire of the same contour operating under the same conditions adjacent to the ventilated sample. Each luminaire was equipped with a 400-watt E-H1 mercury vapor lamp, and reflector surface in both cases is diffuse Alzak process.

It will be noted that the initial curve for both luminaires shows a "narrow" distribution and that the final curve for the ventilated sample is also

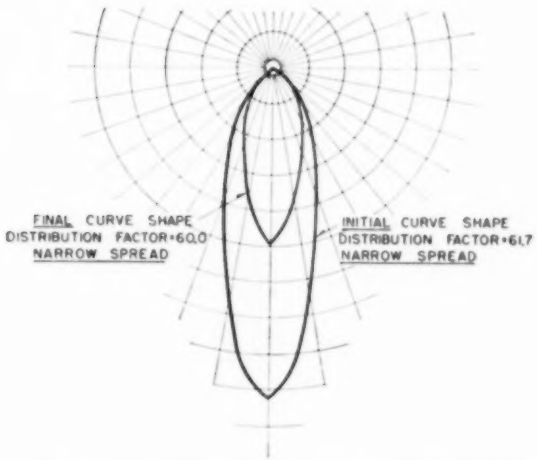


Figure 3. Photometric distribution of a typical ventilated aluminum high-bay unit taken initially and after 1000 hours operation in the foundry area.

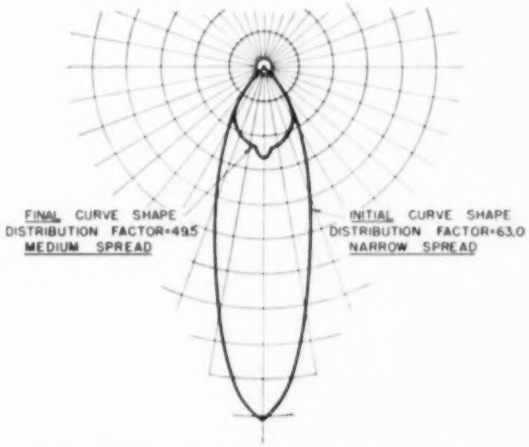


Figure 4. Photometric distribution of a typical unventilated aluminum high-bay unit taken initially and after 1000 hours operation in the foundry area.

"narrow." However, the distribution of the unventilated unit has become "medium" due to additional diffusion of the light by dirt from the reflecting surface and on the lamp. (This effect is even more pronounced where specular reflectors are involved). For the typical samples tested, the following values are indicated:

	Distribution Factors*	
	Initial	Final
Unventilated Luminaire	63.0%	49.5%
Ventilated Luminaire	61.7%	60.0%

In order to fully evaluate the effect of this change in distribution shape it would be necessary to analyze the particular application since the utilization factor may change appreciably as the curve widens with dirt accumulation in unventilated luminaires. In large rooms the change may be negligible whereas in narrow high rooms it will significantly reduce illumination levels.

*Note — Distribution Factor is an arbitrary criterion and equals per cent of total luminaire output included within 0-30° zone. Photometric distribution nomenclature used herein is determined approximately as follows:

Distribution Factor Per Cent	Nomenclature
60 and above	narrow
40-55	medium
35 and below	wide

Within the 55-60 and 30-35 border ranges, nomenclature is determined by inspection of curve shape.

Summary

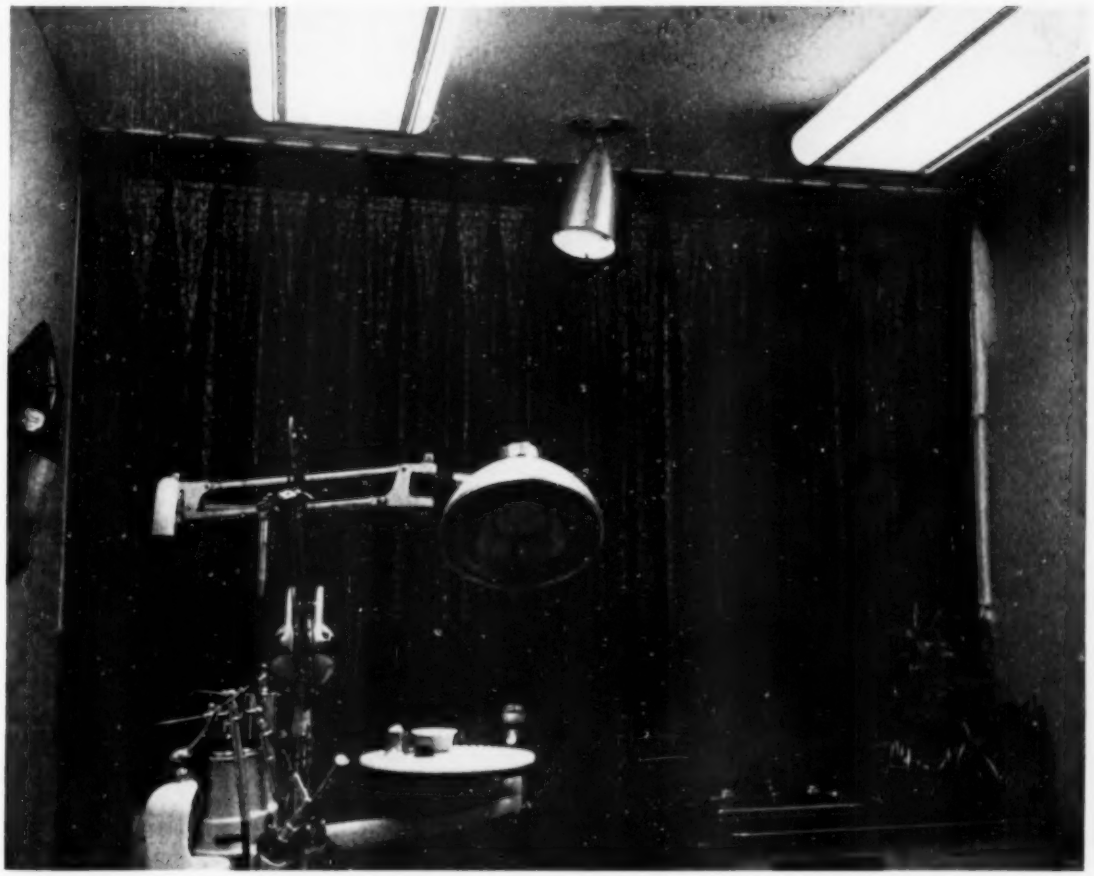
The improvement in maintained overall efficiencies exhibited by ventilated aluminum high bay luminaires will be reflected in higher maintained illumination levels even with extended periods between cleanings. In this connection it is significant to note that the luminaire mean maintenance factor is actually better than the mean lumen output percentage for all commonly used incandescent and mercury vapor lamps.

The improvement in maintained distribution curve shape will also be reflected in higher maintained illumination levels except in large rooms with favorable room index.

In relatively dirty areas, maximum benefit can be realized from the above if at least a "dry wipe" schedule is established at no greater than six-month intervals (preferably at three months or with each incandescent lamp renewal). A thorough wash is advisable at one year intervals or as indicated by inspection. In clean areas, considerably longer schedules are made possible by these luminaires as will be indicated by spot footcandle checks and visual inspection of luminaires. Corrosive conditions are, of course, excepted as are areas where mechanical conditions are severe, in both of which cases heavy duty enclosed luminaires are definitely indicated.

High Level Illumination In Hospital Delivery Room

This delivery room, at the Memorial Hospital of Chester County, West Chester, Pa., provides high levels of illumination for both day and night use. The luminous panel, consisting of 8 x 8-foot sheets of corrugated white acrylic plastic, is mounted below 18 equally spaced 40-watt fluorescent lamps. Illumination level at delivery table height is 110 footcandles. Large window area gives additional light for daytime use. Installation was designed by the Eastern Engineering Co., Reading, Pa. ***Photo courtesy Rohm and Haas Co.***



INSTALLATION AT HOFFMAN DENTAL CLINIC, 4335 W. FOND DU LAC AVE., MILWAUKEE, WISC..

Lighting a Dental Office

LIGHTING OBJECTIVE: To minimize the brightness differences between the area illuminated by the dental spotlight and the rest of the field of view.

GENERAL INFORMATION: The room shown above measures 7' 9" x 8' 9" with an 8' 6" ceiling. Surface characteristics are as follows:

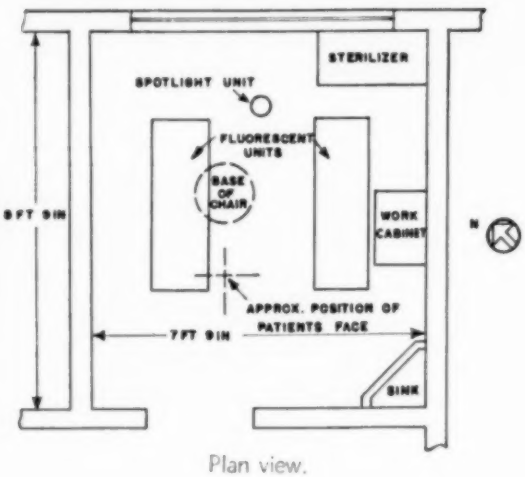
ceiling	white acoustical tile	75% RF
walls		
window wall	maroon	10% RF
other three walls	peach	60% RF
woodwork	light oak	60% RF
floor	gray and white asphalt tile	25% RF
window draperies	maroon	10% RF

The maroon wall and draperies are psychologically warm and comfortable to the patient and are seldom in the dentist's field of view. The top of the work cabinet is black, but when in use for mixing compounds or laying out instruments it is always covered with a white cloth towel.

(over)

A.I.A. File No. 31

Dentist's view.



Plan view.

INSTALLATION: Two Sunbeam #CA1504-48 sty. luminaires with Albalite glass bottoms and diffusing side panels, each containing four 40-watt standard warm white fluorescent lamps, are mounted on the ceiling, one on each side of the chair to:

(a) provide good quality and quantity general illumination for the dentist
(b) minimize reflected glare from brightly polished dental instruments
(c) provide reasonably comfortable lighting for the patient.

In his work the dentist must alternately focus on the patient's mouth and the instrument tray. To minimize the brightness difference between these areas, the tray was covered with replaceable white paper discs and illuminated by a 150-watt R-40 reflector lamp in an adjustable (each dentist has his own particular position for the instrument tray) ceiling-mounted louvered bottom unit (Swivelier #B81).

The resultant illumination levels and brightnesses are as follows:

	ft-c	ft-L
Patient's mouth (with 100-w dental spotlight)	800	200
Instrument tray		
without 150-w R-40 floodlamp	110	
with 150-w R-40 floodlamp	150	120
Patient's face	110	50
Top of work cabinet	85	
Side wall (in dentist's field of view while working on patient)		16
Rear area of room, 30 inches above floor near wall	50	

Designer: Paul Louis Diek and Associates; consulting engineer: Walter E. Brown; electrical contractor: North Side Electric Co.; lighting engineer: William C. Kuhnke.

Lighting data submitted by William C. Kuhnke, Wisconsin Electric Power Co., 231 West Michigan St., Milwaukee as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Series XVIII 4-53

The Use of Zonal Constants in the Calculation of Beam Flux

From Candlepower Distribution Data

By THEODORE H. PROJECTOR

THE LUMINOUS FLUX in the beams from searchlights, floodlights, and other projection lighting equipment is frequently calculated from candlepower distribution data with the aid of tables of zonal constants. The beams are divided into convenient zones and the flux in each zone is obtained by multiplying the average candlepower in the zone by the solid angle subtended by the zone at the light source (the zonal constant). For axially symmetrical beams (where a cross-section of the beam is radially symmetrical), annular zones are convenient, and the constants may be computed readily from the formula:

$$\text{Zonal Constant} = 2\pi(\cos\alpha_1 - \cos\alpha_2) \qquad (1)$$

where α_1 and α_2 are the plane angles defining the inner and outer limits of the zone, respectively. As early as 1908, Weinbeer published a table of constants for annular zones at 10-degree intervals,[1] and many similar tables have been published since then, giving constants for zones at 1-, 2-, 5-, and 10-degree intervals.[2,3]

In the event that the beam from the projector is not axially symmetrical, more finely subdivided zones must be selected. Zones may be defined in a number of ways and the method selected in any given case is determined principally by the type of goniometer used and the availability of tables of constants. If the goniometer used measures cone angles (the angles that define annular zones) and polar angles (angles around the optical axis of the test equipment) then subdivision of annular zones into segments is practical. For a zonal segment defined by two cone angles, α_1 and α_2, and by two polar angles, β_1 and β_2, the zonal constant is given by:

$$\text{Zonal Constant} = \frac{\beta_2 - \beta_1}{360} 2\pi(\cos\alpha_1 - \cos\alpha_2) \qquad (2)$$

(β_1 and β_2 are expressed in degrees.)

If zonal constants for annular zones (α_1, α_2) are available, they may be used to compute segmental constants. It is evident by comparison of equations (1) and (2) that zonal constants for segments defined by α_1, α_2, β_1, and β_2 are given by:

$$\left(\begin{matrix}\text{Zonal}\\ \text{Constant}\end{matrix}\right)_{\alpha_1\alpha_2\beta_1\beta_2} = \frac{\beta_2 - \beta_1}{360}\left(\begin{matrix}\text{Zonal}\\ \text{Constant}\end{matrix}\right)_{\alpha_1\alpha_2} \qquad (3)$$

Goniometers suitable for cone angle measurements are occasionally used but the majority of goniometers employed in projection photometry are of the types illustrated in Fig. 1.[4,12*] In these, a direction of measurement in the beam is given by a "horizontal" and a "vertical" angle. In a type A goniometer, "vertical" angles are measured around a fixed horizontal axis of rotation while "horizontal" angles are measured around an axis which is vertical only when the "vertical" angle is zero (as shown) or 180°. In a type B goniometer, "horizontal" angles are measured about a fixed vertical axis and "vertical" angles are measured about a movable horizontal axis. It may be emphasized at this point

*See following article: "Versatile Goniometer for Projection Photometry."

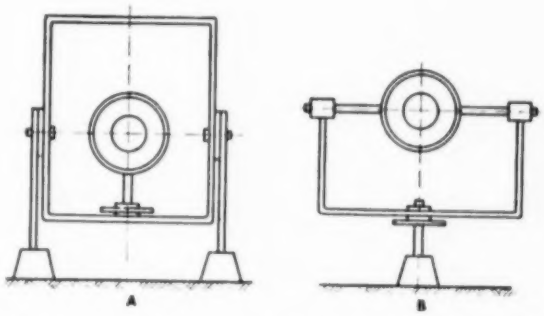


Figure 1. (After Bergmans and Keitz, 1947) The type A goniometer measures "vertical" angles about a fixed horizontal axis and and "horizontal" angles about an axis which is vertical at zero "vertical" angle (beam horizontal) but is inclined from the vertical as the "vertical" angle is moved from the zero position. With the type B goniometer, "horizontal" angles are measured about a fixed vertical axis of rotation and "vertical" angles are measured about a horizontal axis which rotates as the "horizontal" angle is changed.

AUTHOR: National Bureau of Standards, Photometry and Colorimetry Section, Washington, D. C

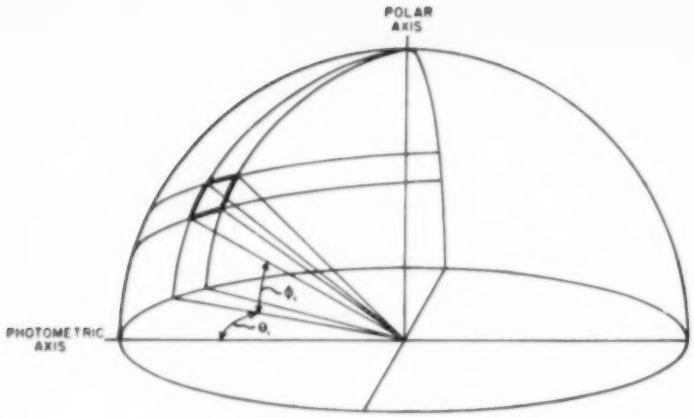


Figure 2. Geometrical construction of spherical quadrilateral zones for type A goniometers. θ_1 is the "horizontal" angle and ϕ_1 is the "vertical" angle to the corner of the zone nearest the photometric axis. When the goniometer is swung through the angles θ_1 and ϕ_1 this corner of the zone is coincident with the photometric axis.

that this is the most obvious distinction between the two types of goniometers: in a type A goniometer, the horizontal axis is fixed, and in a type B goniometer, the vertical axis is fixed.

For computation of flux from candlepower measurements made with a type A or a type B goniometer, "square" or "rectangular" zones are selected and are defined as spherical quadrilaterals, each bounded by arcs corresponding to two horizontal and two vertical angles set on the goniometer. Although two arcs on opposite sides of the quadrilateral represent equal angular intervals as measured on the goniometer, they are not in general equal in length. The solid angle subtended by any given quadrilateral zone depends on which type of goniometer is in use.[4] The manner in which spherical zones are defined is illustrated in Figs. 2 and 3, corresponding respectively to the goniometers shown in Figs. 1A and 1B. In these figures, the "photometric axis" is the direction from which horizontal and vertical angles are measured. To present the nearest corners of the outlined zones to the photometer, the goniometer is swung through horizontal angle, θ_1, and vertical angle, ϕ_1. In type A goniometers (Fig. 2), horizontal angles are meridional and vertical angles are latitudinal, while the reverse is true in type B goniometers (Fig. 3). The polar axes indicated in the figures are the axes through the intersections of the meridians. The polar axes correspond to the movable axes of rotation on the goniometers of Fig. 1 rather than to the axes that remain physically fixed.

Zonal constants for a Type A goniometer (geometry of Fig. 2) may be computed from the formula:

$$\text{Zonal Constant} = \pi \frac{\theta_2 - \theta_1}{180} (\sin \phi_2 - \sin \phi_1) \quad (4)$$

where ϕ_1 and ϕ_2 are the vertical angles θ_1 and θ_2 are the horizontal angles (measured in degrees) bounding the spherical quadrilateral zone. If the goniometer is of type B then the horizontal angles, θ, and the vertical angles, ϕ, must be interchanged in the formula.

Thus the zonal constants for zones defined by "horizontal" and "vertical" angle boundaries must

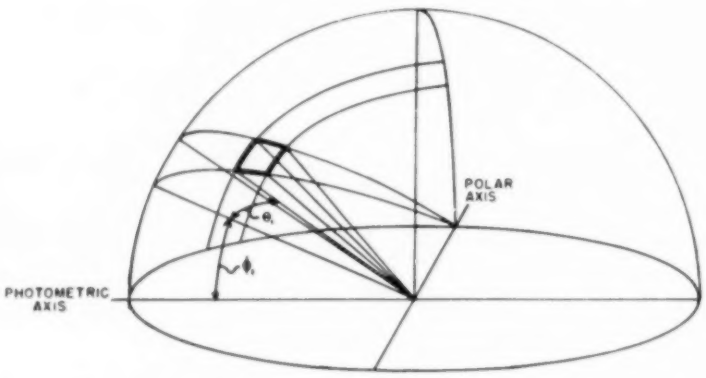


Figure 3. Geometrical construction of spherical quadrilateral zones for type B goniometers. As in Fig. 2, θ_1 is the "horizontal" angle and ϕ_1 the "vertical" angle to the corner of the zone nearest the photometric axis.

be specified for angles measured with one of the two types of goniometers. If the goniometer used is not of the type for which the constants in a table are computed, correct constants can be obtained by interchanging the horizontal and vertical angle designations in the table. To assist in determining the type of goniometer for which zonal constants are given, it is especially helpful to note that the angular arguments in a table are always the settings made around the fixed axis of rotation of the goniometer.

The distinction between the two types of goniometers has not been made very clear in any of the published tables of zonal constants for "square" or "rectangular" zones, and recently, in fact, tables have been published in which the goniometer type has not been mentioned at all. In 1927, the Association of Railway and Electrical Engineers published a report on "A General Procedure for Photometry of Incandescent Floodlights,"[5] later incorporated into an I.E.S. Testing Specification, "Testing Procedures for Narrow Beam Inclosed Projectors,"[2] which included zonal constants for "square" zones. A description of a recommended goniometer of type B and a brief discussion of its geometry was included in the accompanying text but without any warning that goniometers may be of type A and that in such a case, the tables would have to be used with the precautions described in this paper. In a subsequent revision of the I.E.S. Testing Specification[6] the textual material pertaining to the design of the recommended goniometer and the discussion of the geometry of the zones was repeated but the column heading in the tables which had previously been designated "horizontal angle" was now labeled merely "angles," thus adding further to the possibility of misuse.

Tables of zonal constants for the type B goniometer have been republished and extended since the publication of the revised I.E.S. Testing Specification in 1936, but in all of the published sources that have come to my attention, including the *I.E.S. Lighting Handbook*, no mention at all is made of the fact that the tables are computed for type B goniometers.[3,7,8,9] Two tables of constants for type A goniometers have appeared.[10,11] Both were published for use in the photometry of street lighting luminaires and the texts clearly described distribution photometers with type A goniometers.

It is recommended therefore that notations be made on tables of zonal constants that may be used for reference, describing the type of goniometer for which the tables are computed, and noting that if a goniometer of the other type is to be used, the tables are valid provided that the angular arguments are taken as the angles about the fixed axis of rotation.

References

1. E. W. Weinheer: "A Simple Method of Determining the Mean Spherical Intensity of a Source of Light," *Illuminating Engineer*, London, Vol. 1 (1908).
2. "Testing Procedures for Narrow Beam Inclosed Projectors," *Trans. I.E.S.*, p. 494 (June 1933).
3. *I.E.S. Lighting Handbook*, Second Edition, p. A 20 and p. A 22 (1953).
4. J. Bergmans and H. A. E. Keitz, "Determining the Light Distribution and Luminous Flux of Projectors," *Philips Technical Review*, p. 114 (1947).
5. "General Procedure for Photometry of Incandescent Floodlights," *Proc. of Assoc. of Railway Electrical Engineers*, p. 133, Vol. 18 (1927).
6. "Testing Procedure for Narrow Beam Enclosed Projectors," *Trans. I.E.S.*, p. 508 (May 1936).
7. "Specifications for Testing Lighting Equipment. Section II. Incandescent Filament Floodlights," ILLUMINATING ENGINEERING, p. 671 (June 1941).
8. "Photometric Testing Procedure for Searchlights," NEMA Standard FL8-10 (May 1945).
9. "I.E.S. Guide for the Photometric Testing of Floodlights of 10-160 Degrees Total Beam Spread," ILLUMINATING ENGINEERING, p. 163 (March 1951).
10. G. A. Horton: "Modern Photometry of Street Lighting Luminaires," ILLUMINATING ENGINEERING, p. 989 (November 1948).
11. "I.E.S. Guide for Photometric Testing of Street Lighting Luminaires — 1948," ILLUMINATING ENGINEERING, p. 416 (July 1949).
12. H. J. Turner: "The Use of Sinusoidal Webs in Plotting Light Distributions from Fluorescent Lamp Fittings," Light and Lighting, p. 218 (September 1949) and Corrigenda, ibid., p. 322 (November 1949).

Subscriptions to New I.E.S. Lighting Data Sheets—Series XVIII

You can tell it's Spring when you see the first announcement of a new 24-sheet series of I.E.S. Lighting Data Sheets. Series XVII has now become part of the vast file of these excellent lighting jobs, turned out since 1928, and subscribers will be looking forward to receiving the first eight of the brand-new Series XVIII in a few months. Not only have many persons been making sure of a constant supply of these individual sheets solving out-of-the-ordinary lighting jobs for their own use, but many companies are using them in quantity as idea-stimulators for their customers and prospects, making three regular mailings of eight sheets each during the subscription year.

Why not start your personal file of I.E.S. Lighting Data Sheets with Series XVIII and a special binder for them? Or make these official, authoritative I.E.S. publications a part of your sales promotion program? Make sure you are on the list to receive the first mailing in May. Remember, I.E.S. Lighting Data Sheets are printed on heavy, coated 90-pound stock to keep them clean and durable and are punched to fit standard binders.

Versatile Goniometer For Projection Photometry

By THEODORE H. PROJECTOR

A GONIOMETER of unusual versatility and precision has been designed and constructed for use on the 100-foot photometric range at the National Bureau of Standards. The new goniometer incorporates a table with T-slots for mounting test equipment, a choice of goniometric geometries, provision for minimizing errors due to backlash and torsion, and is generally constructed for optimum rigidity and convenience.

Goniometers for general purpose photometric ranges must meet severe requirements. Test equipmnt may vary in weight over a very wide range and the distribution of weight and bulk may be quite variable. For longer searchlight ranges, accuracies of the order of $\pm 0.05°$ or better are required and goniometers must be massive to accommodate heavy bulky searchlights without severe angular distortion.

Searchlights and other large, narrow-beam projectors are measured at the National Bureau of Standards on a 900-foot range using a goniometer constructed from a 60-inch searchlight,[1] but smaller equipment is measured on the 100-foot range. Because of the great variety of equipment measured on the 100-foot range and the many types of photometric measurements made, it was necessary to design a goniometer having considerable flexibility.

As noted in the previous paper,* conventional goniometers have two axes of rotation, one for measuring "horizontal" angle and the other for measuring "vertical" angle, although occasionally, goniometers are designed in which cone angles are measured around one axis and polar angles around the other axis.[2] In the discussion of the geometry of goniometers, it was shown that goniometers measuring "horizontal" and "vertical" angles may be divided into two types, A and B, depending on which of the axes of rotation is fixed. The new NBS goniometer has been designed to permit use as a type A or B goniometer or, if desired, the goniometer may be used for cone and polar angle measurements.

*The Use of Zonal Constants in the Calculation of Beam Flux from Candlepower Distribution Data. (This issue, p. 189.)

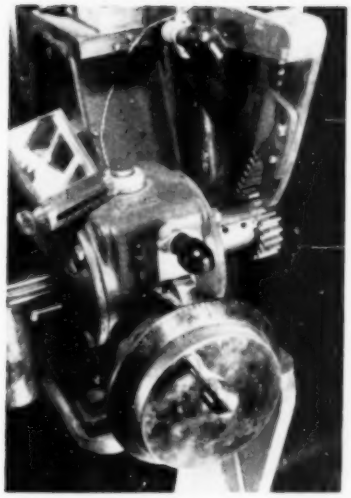
AUTHOR: National Bureau of Standards, Photometry and Colorimetry Section, Washington, D. C.

Construction of New NBS Goniometer

Fig. 1 is a photograph of the new goniometer. Three axes of rotation are provided: two for measuring "horizontal" angles and one for "vertical" angles. In any given set of measurements, only one of the two "horizontal" angle rotations is used, the choice being dependent on the desired goniometric geometry or on the mounting requirements of the test equipment. The "horizontal" angle rotations are obtained with rotary tables of the type used on machine tools. The lower rotary table, with a table surface 25 inches in diameter, is attached to a heavy welded base frame. The frame is leveled and supported on eight adjustable pads which may be raised if necessary to permit moving the goniometer on its casters. An outer U-frame made of welded iron channels is mounted on the lower rotary table.

A second, inner, U-frame, constructed from lengths of iron pipe welded together, is mounted

Figure 1. New NBS goniometer for 100-foot photometric range. Three axes of rotation are provided, instead of the conventional two. By selection of the proper rotations and suitable orientation, measurements of type A or type B "horizontal" and "vertical" candlepower distributions, or of distributions with respect to cone and polar angles may be made.



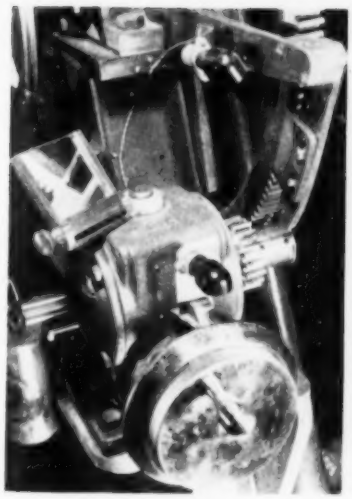
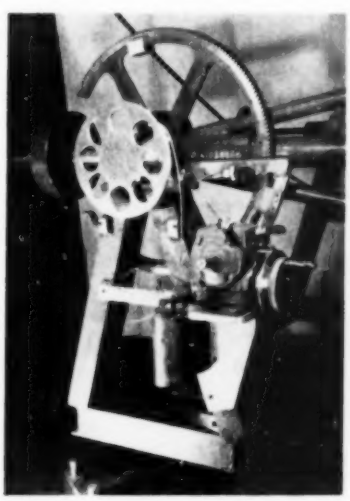


Figure 2. Close-up of "vertical" angle drive. To balance the inner U-frame of the goniometer, the pinion gear at the right in photos, shown engaged with the sector gear in Fig. 2a (left), is disengaged by sliding it along its shaft to the position shown in Fig. 2b (right).

within the outer U-frame. The inner frame may be rotated around a horizontal axis extending through ball bearings set on pedestals at the tops of the arms of the outer frame. The handwheel drive for this "vertical" angle rotation is linked to the inner U-frame by a gear reducer, a pinion, and a large sector gear, all at the left in the picture. A pair of fixed counterweights is attached to the ends of tubular shafts on each arm of the inner U-frame to balance the frame about its axis of rotation. In addition a pair of adjustable weights is provided to permit balancing the frame with test equipment mounted in place.

Test equipment is usually mounted on the upper rotary table, set at the bottom of the inner U-frame, utilizing the T-slots in the 15-inch surface plate. A collection of T-head bolts, spacers, clamping bars, etc., is provided, to facilitate rigid mounting and alignment of a variety of test equipment without special setup work.

To balance the inner frame after the test equipment is mounted on the rotary table, the pinion gear is disengaged from the large sector gear by depressing the small spring-loaded locking pin visible in Fig. 2a and sliding the pinion along its shaft until it has cleared the sector as shown in Fig. 2b. The inner frame is then freely rotated until the arms are horizontal, in which position the balancing weights may be adjusted easily and balance determined accurately. During balancing, the small weight at the far left in Fig. 1 is disconnected from the pulley as shown in Fig. 3a. When balancing is completed and the pinion gear is re-engaged with the sector, the weight is replaced on



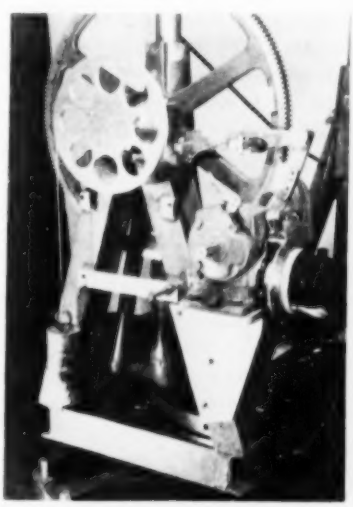


Figure 3. During balancing of the inner U-frame, the small weight used to apply a constant torque to the frame is removed from its pulley as shown in photo at left. When balancing is completed and the pinion gear re-engaged with the sector as in Fig. 2, the weight is replaced on the pulley as shown at right.

the pulley as in Fig. 3b. With the inner frame balanced and the small weight in place, a constant torque of about four pound-feet is applied to the frame at all settings of the "vertical" angle.

The two rotary tables have scale markings at the edges of their surface plates graduated in degrees. The lower table has a graduated dial, attached to its drive shaft, with scale graduations at intervals of 0.05°. The drive shaft dial of the upper rotary table is graduated at intervals of 0.1°. Fractions of the smallest intervals on both dials may be estimated when necessary. The large sector gear is graduated on its outer face at the periphery in degrees (see Fig. 3) and a vernier index may be used to read the "vertical" angle to 0.1°. A small adjustable mirror is mounted on the top of the gear reducer (see Fig. 2) so that the graduations on the outside of the sector gear may be read by an operator behind the goniometer on the other side of the sector. The dial on the handwheel for the "vertical" angle drive is graduated in hundredths of a degree. Small lighting fixtures provide illumination for all the angle scales.

The worm drives on both rotary tables may be disengaged to permit free rotation of the tables as required to facilitate rotation through large angles.

Goniometric Geometry

For most photometric work, the upper rotary table is used for "horizontal" angle measurement together with the drive for the inner frame for "vertical" angles. This combination constitutes a type A goniometer, as described in the previous paper, in which the axis of "vertical" angle measurements (the horizontal axis) remains fixed and the axis of "horizontal" angle measurements rotates as the "vertical" angle setting is changed. If the geometry of a type B goniometer is desired, then the lower rotary table is used instead of the upper one and the axis of "horizontal" angle measurements is the fixed one. Since, for most work, the choice between A or B geometry is not important, the choice of the type A geometry is usually made with the new goniometer because of the greater ease of operation of the upper table. However, apart from the choice of geometries, the lower table has been found useful occasionally, when it was necessary to mount test equipment in such a way that the upper table could not be rotated either because the test equipment was too bulky to clear the arms of the inner frame or because the inner frame was used in the mounting of the test equipment.

For cone angle measurements, the inner U-frame is rotated into the position where its arms are horizontal, and the beam from the test equipment projects horizontally through the open end of the U-frame toward the photometer. From this position of the inner frame, cone angles are set by rotation of the inner frame (the "vertical" angle drive when the goniometer is of type A or B) and polar angles are set by rotation of the upper rotary table.

Accuracy

Backlash and variable torque errors in "vertical" candlepower distributions have been greatly reduced in the new NBS goniometer by the provision of the adjustable balancing arrangement and the constant torque device. Backlash errors are minimized in conventional goniometers by rotating the goniometer in one direction only during a traverse. This is generally satisfactory for horizontal traverses when the axis of rotation is vertical and the only torque involved is that of friction in the drive system and bearings. However, in a vertical traverse, there may be considerable variation in the torque loading on a goniometer lacking a balancing arrangement, as the goniometer is rotated. In many cases, the goniometer will pass through a balance point during the traverse, with torques of opposite sense applied on either side of the balance point. Under these conditions, backlash errors may be large and may vary considerably from test to test. (It should be noted that backlash errors due to variable torque, including occasionally a reversal of the sense of the torque, may occur under certain conditions with horizontal traverses taken on a type A goniometer. In this type, the axis of rotation for the horizontal traverse may depart appreciably from the vertical. If the test equipment is asymmetrical in weight distribution about the axis, then the torque applied may vary during the horizontal traverse, depending on the amount of asymmetry, the angles traversed, and the inclination of the axis from the vertical. With the new NBS goniometer, this can be avoided, if other considerations permit, by using the type B combination, in which the axis of horizontal traverses remains fixed vertically.)

Since the adjustable balancing weights on the new NBS goniometer are confined to positions along the arm extensions of the inner U-frame, it is not possible to balance the frame with the weights for all "vertical" angle settings if the center of gravity of test equipment cannot be made to lie in the plane of symmetry of the frame containing the axis of rotation. Balance for all angular settings may be achieved in such a case by a two-step process. First the balancing weights are moved along the arm extensions to the innermost position nearest the axis of rotation. The inner frame, with the pinion disengaged, will now hang like a pendulum with the rotary table near its lowest position and the arms nearly vertical. The departure of the arms from the vertical is a measure of the asymmetry of the center of gravity of the test unit.

Weights are then fastened to the inner U-frame, as required, to balance the test unit about the plane of symmetry. Balance is indicated by the arms being vertical. The inner frame is then rotated 90° and balancing with the adjustable weights is done as previously described. After this double balancing operation, the goniometer has been fully balanced and backlash error throughout any vertical traverse is avoided.

Although backlash error is the most usual source of error found in goniometry, an error due to variable torsion may sometimes occur. In any goniometer similar to the new NBS goniometer the driving torque delivered to the inner U-frame is delivered to one side of the frame only. If the weight distribution of the equipment under test is asymmetric with respect to the vertical plane in which the axis of the upper rotary table rotates during a vertical traverse, then under certain conditions, a torsional stress, varying with "vertical" angle, may be applied to the inner frame, resulting in a distortion of the frame and a consequent error in the "vertical" angle measurement. Torsional errors of this type have been kept to a minimum by the rigid welded construction of the inner frame. In case of seriously asymmetrical loading, some compensation may be obtained by unequal setting of the two adjustable counterweights, but no provision has been made for accurate compensation of this type, and the extent of the required inequality of the settings must be estimated.

Ideally in projection photometry, the equipment under test should be mounted on the goniometer in such a way that the effective center of the aperture of the unit is coincident with the center of rotation of the goniometer. (It is frequently difficult to ascertain with precision the effective center of the aperture, but the uncertainty usually involves negligible photometric error.) It is conventional on photometric ranges to set the photometer at the same height as the center of rotation of the goniometer. When the center of aperture of the test unit is located at the center of rotation of the goniometer the photometric distance is equal to the range length (the distance between the center of rotation of the goniometer and the photometer) throughout any traverse.

The first step in obtaining this coincidence is to mount the test unit on the horizontal surface of the mounting plate (with the goniometer at zero "vertical" angle) so that a vertical line through the center of aperture passes through the center of rotation. The next step is to adjust the height of the test unit so that complete coincidence is achieved.* The first step is usually easily made simply by proper location of the test unit on the mounting surface. The second step is often more difficult. In some goniometers, the second adjustment is obtained by a built-in vertical adjustment of the mounting surface plate. Such a built-in adjustment has not been incorporated into the new NBS goniometer, since it was felt that the added convenience would be more than offset by the increased mechanical complexity of the goniometer and the difficulty of maintaining adequate rigidity in the goniometer structure to insure high angular accuracy. The permanent location of the upper rotary table is such that for most work the vertical height of the test unit with a simple mounting will fall very near the center of rotation or a few inches below it. In the latter case, the unit may be raised the necessary distance by the insertion of simple spacers between it and the mounting plate.

In order to determine the accuracy required in mounting a test unit, or conversely, to determine the errors resulting from any degree of inaccuracy in the mounting, it is customary in each case to make simple calculations based on the required photometric measurements and the geometry of the range. In almost all cases, the total error can be made negligible with relative ease. The total error consists of two parts: (1) the error in the measurement of distribution angles due to any angular difference between the range axis, or the line connecting the center of rotation of the goniometer with the photometer, and the actual photometric axis, or the line connecting the center of the aperture of the test unit with the photometer, and (2) the error due to any difference between the nominal photometric distance and the actual distance between the center of aperture of the test unit and the photometer.

The error in angle measurement may be of two types. The first type of error arises when angular measurements in a distribution are made with respect to an external reference direction such as the range axis. The second type arises when angle measurements are referred to an axis determined in the course of the measurements, such as the direction of peak candlepower in the traverse.

Suppose for example, that a test unit is mounted on the upper rotary table in such a way that its center of aperture is four inches below the center of rotation of the goniometer. Suppose further that a mechanical axis is indicated on the test unit and that when the unit is mounted on the horizontal surface plate, this axis is horizontal. The photometer is then four inches above this axis. For a range distance of 100 feet, the candlepower measurement at what is indicated as zero "vertical" angle will actually be made at an angle above zero equal in radians to the ratio 4 inches to 100 feet = 1/300 radian = 0.2 degree. If this error is not

*The airport boundary light shown in Fig. 1, is mounted below the center of rotation. It will be shown later that errors due to off center mounting are often negligible.

negligible, the height adjustment must be improved, or the angle measurement corrected.

In the event that the error in the measurement of angular interval within a traverse (the second type of error) is of primary concern in the above case, then the length and direction of the traverse and the actual angles traversed must be considered in determining the error. Suppose that a 60-degree vertical traverse is to be taken with 30 degrees lying on either side of zero "vertical" angle. The error in the measurement of the angular interval between the center and either end of the traverse, arising from the mounting height being four inches too low will be less than 0.03 degree.

The maximum error in the photometric measurement in this example due to the difference (2 inches) between the nominal photometric distance of 100 feet and the actual photometric distance will occur at the ends of the traverse and is equal to 0.33 per cent.

Measurements of the angular accuracy obtainable with the new NBS goniometer have been made by comparing angular intervals measured with a transit mounted on the goniometer with those indicated by the goniometer. The transit was mounted on the upper rotary table in place of a test unit. The results are summarized in the following table:

	Maximum error, in degrees, of the measurement of any angular interval in a traverse when the total traverse length is:				
	1°	3°	10°	30°	90°
Upper rotary table	0.02	0.02	0.02	0.03	0.03
Lower rotary table	0.02	0.02	0.02	0.03	0.03
"Vertical" angle drive	0.02	0.03	0.04	0.05	0.10

The assistance of various members of the Photometry and Colorimetry Section at the National Bureau of Standards who contributed suggestions and advice, and of the Shops Division where the basic goniometer was constructed and many design details worked out, is gratefully acknowledged.

References

1. F. C. Breckenridge and T. H. Projector: "Construction of a Goniometer for Use in Determining the Candlepower Characteristics of Beacons," CAA Technical Development Report No. 39 (February 1944).
2. J. Bergmans and H. A. E. Keitz: "Determining the Light Distribution and Luminous Flux of Projectors," *Philips Technical Review*, p. 114 (1947).

Louverall Lighting in Hospital Lobby

A louverall ceiling is used to cover the beams and air-conditioning ducts which clutter the ceiling of the lobby area of the Esso Standard Bayway Refinery Hospital, in Bayway, N. J. Strip lights in symmetrical Alzak aluminum reflectors are mounted above 3 x 3-foot panels of translucent plastic louvers. Average level of illumination at counter height is 55 ft-c. Average brightnesses are: ceiling — 45 ft-L; side walls — 20 ft-L; floor — 10 ft-L; counter tops — 40 ft-L. Side walls are finished in light yellow; floor is mottled green asphalt tile; counter tops are of plastic material with a reflectance of approximately 20 per cent. The glass brick below the counters provides a decorative touch.

Photo and data supplied by J. M. Arthur, Graybar Electric Co., Long Island City, N. Y.

An Appraisal of Illumination Calculations For Luminous Indirect Luminaires

By ROBERT D. BURNHAM

IT IS generally agreed that luminous indirect luminaires provide a high quality illumination. When properly designed and coordinated with the room, they control both direct glare and brightnesses in the reflected glare zone. However, in some cases, there has been some reluctance to the use of luminous indirect because of the so-called "low" utilization of light. With the increased interest in luminous indirect luminaires for critical seeing areas, it was discovered that the average illumination level predicted by most published data was considerably lower than the illumination level actually received. This stimulated further investigation to determine what error is encountered in calculations normally used for such installations. After checking several existing installations, it was found that the average maintained illumination was in the order of 20 to 40 per cent higher than anticipated using the Harrison-Anderson method of calculation with existing tables.

There are at least three factors which contribute to make the present day calculations lower than the measured values. These three are:

1. Ceiling and wall reflectances are often higher than anticipated.
2. Maintenance factors are sometimes not realistic.
3. Published coefficient of utilization tables are often low.

These three factors all contribute to give a sizeable error.

Room Reflectances

Due to the increase in reflectances recommended by the Illuminating Engineering Society and other interested groups and the improvement in paint reflectances by the paint industry, the average room reflectances found today are considerably higher than those encountered a few years ago. The majority of the coefficient of utilization tables published today are based on a maximum ceiling reflectance of 75 per cent.

In search for facts, the ceiling reflectances in a number of schools and offices were measured to determine what a realistic ceiling reflectance might be. It was found in most of these cases the reflectance remained above 80 per cent, although in many rooms the ceiling had not been painted for three or four years. It is not at all uncommon for white painted ceilings to have an initial reflectance of 85 per cent. It seems conservative, therefore, to use a ceiling reflectance of from 80 to 85 per cent for illumination calculations. With luminous indirect luminaires, the resulting illumination will not fall off proportionally to the ceiling reflectance. In an average size room with 50 per cent walls, a 10 per cent increase in ceiling reflectances will reflect a 15 per cent increase in illumination.

Reflectance factors of walls in critical seeing areas are often in the order of 50 to 65 per cent. Most coefficient of utilization tables do not go above 50 per cent. Another column might be added to the coefficient of utilization tables for 65 per cent walls which would enable more accurate calculations.

The floor reflectance in Harrison-Anderson method is assumed to be 14 per cent. With the use of luminous indirect, interflection is depended upon quite heavily for the build-up of illumination; therefore, higher floor reflectances are quite often used. The error encountered due to an increase in floor reflectance from 14 per cent to 30 per cent may affect the resulting illumination only a few per cent or up to 15 per cent depending upon room size. It might be well to consider adding an additional set of tables with higher floor reflectances for luminous indirect fixtures. There are proportions suggested for use with the Harrison-Anderson tables to increase the coefficients when higher reflectances of ceiling, walls and floors are used but *too often these factors are not employed.*

Realistic Maintenance Factors

There are at least three factors which contribute to the illumination depreciation and are assumed to be compensated for by means of a maintenance factor. One important factor is lamp depreciation. The mean light output of a fluorescent lamp usually used in a fixture of this type is 19 per cent less than the initial lumen output after 100 hours of burning. A second factor is the depreciation due to the soiling of ceiling and walls. The third factor is the depreciation of light output of the luminaire due to accumulation of dirt on lamps and reflecting surfaces.

AUTHOR: Illuminating Engineer, The F. W. Wakefield Brass Co., Vermilion, Ohio.

Figure 1. A portable blower is used to dislodge dust accumulation on luminaire and lamps.

Fifteen surveys were made in the Midwest covering offices and schools in varying conditions such as offices in industrial areas to schools in clean residential areas. The maintenance factors proved to be from 65 to 75 per cent. This shows a drop in illumination level from 25 to 35 per cent. Subtracting the 19 per cent for the mean light output of lamps shows a 6 to 16 per cent drop due to fixture depreciation under existing maintenance conditions. The depreciation of room surfaces has no effect since calculations were based on the reflectances measured at the time of survey.

One simple means of maintaining open-topped luminous indirect luminaires takes the form of a small blower with hose attachment (See Fig. 1). The maintenance man simply blows out each row of luminaires by projecting the nozzle over the edge of the fixture trough and walking along each row blowing out the trough as he goes. Preliminary tests show that by blowing out the fixtures every two to four weeks the illumination depreciation due to fixture dirt accumulation can be as low as 5 per cent. This method allows fixture maintenance for the most part to be handled from the floor. The fixtures are then washed once a year to once every two years, depending on dirt conditions.

Coefficient of Utilization

In order to check the possible error in the coefficients of utilization, a typical room was surveyed and the results analyzed. This room was a classroom 23 feet 6 inches wide, 35 feet 3 inches long with a ceiling height of 11 feet 9 inches. The reflection factor of the ceiling was 82 per cent; walls, 62 per cent; and floor, 15 per cent. The room was illuminated with 21 two-lamp, 40-watt luminous indirect luminaires. The fixture efficiency was 71 per cent. The illumination survey was made in accordance with footcandle survey Form IS-10 prepared by the Illuminating Engineering Society. All illumination readings were taken with a Weston Model #756 illumination meter which was cosine and color corrected and recently calibrated. All survey work was done at night to eliminate any influence of daylight. Fig. 2 is a graph showing a comparison

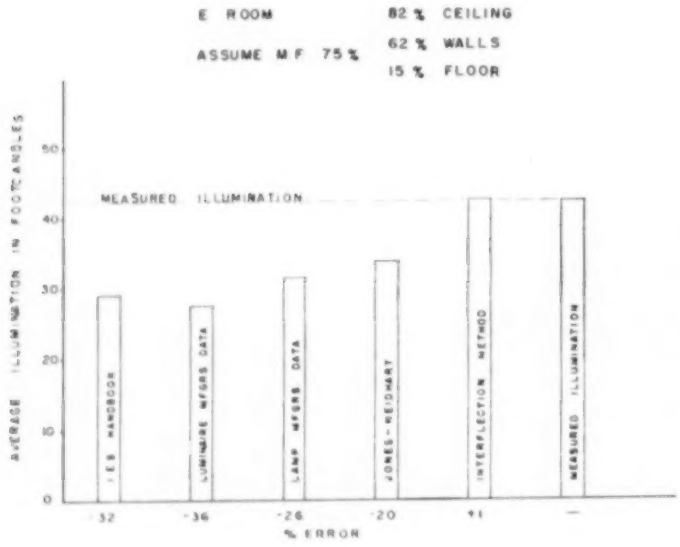


Figure 2. Several sources of data were used to predict the illumination in an E room. The first four bars are based on top published reflectances; 75 per cent ceilings, 50 per cent walls, actual room reflectances as shown. The results and per cent error are shown. The maintenance factor in each case is assumed to be 75 per cent.

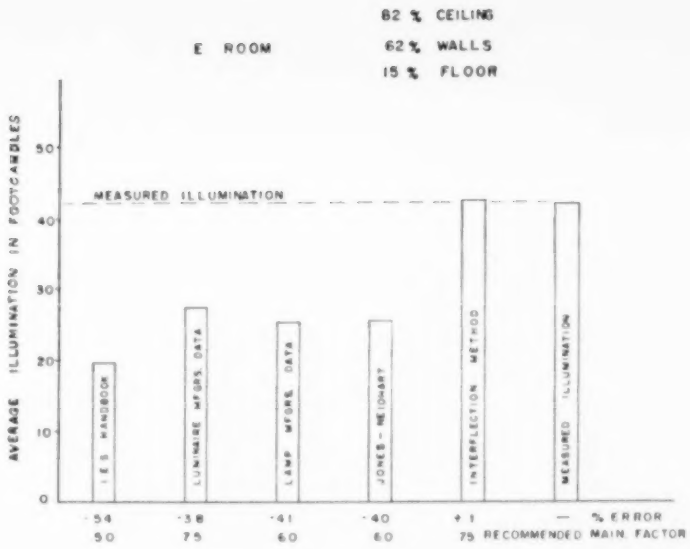


Figure 3. This graph is the same as Fig. 2, except the maintenance factor suggested by the data source is used in each case. The error is emphasized.

between the actual measured value in this particular room and the calculated values. No correction for higher reflectance levels for the first three bars calculated by Harrison-Anderson and the fourth bar calculated by Jones-Neidhart was used since these data have not been readily available to the application engineer. These fixtures have been in operation for a period of three and a half years and have not been washed for seven months. The room had been painted three years previous to the time of test. Under these conditions a maintenance factor was selected at 75 per cent and calculations for Fig. 2 are based on this maintenance factor. The first three graphs are based on the Harrison-Anderson method and are considerably lower than the measured value. Fig. 3 shows the same calculations applying the recommended maintenance factor in each case. The error is emphasized by the low coefficient of utilization and low maintenance factor.

The first three bars of the bar graph in Fig. 3 are based on the Harrison-Anderson method using the top reflectances, which were 75 per cent ceiling and 50 per cent walls. The *I.E.S. Lighting Handbook* suggests a proportional increase for wall and ceiling reflectances. Using these tables the calculated illumination for this room was 19.4 footcandles after applying a recommended maintenance factor of 50 per cent. This illumination value was increased for an 82 per cent ceiling and a 62 per cent wall reflectance. A weighted floor reflectance was calculated to compensate for the effect of desk reflectances. This factor was applied. A seven per-cent increase was allowed for error in measurement since the original Harrison-Anderson tests did not have cosine corrected equipment available at that time. The lamps in the test room were photometered at operating voltage and a correction applied for the difference between the measured value and the published mean light output. This brought the calculated illumination up to 29.1 footcandles. A 31 per cent error remains although these factors were applied. The error now lies largely in the maintenance factor.

It appeared that in this instance the interflection method of calculating illumination approached more closely the actual illumination than any of the other methods. Rooms of varying sizes were selected and surveys made to determine the accuracy of this method. The results are shown in Table I. The per cent of error encountered was well within the anticipated error. The accuracy of the testing procedure was no better than five per cent and there were other factors for which there was no compensation such as the effect of furniture in the room. The interflection method follows quite closely with the actual performance of luminous indirect luminaires and this method seems to be

TABLE I.—Survey of Existing Installations.

Existing Installation	Kr	Calculated Footcandles	Measured Footcandles	Per Cent Error
Classroom	.42	31.7	33.5	5%
Classroom	.53	39.0	40.0	2%
Classroom	.39	20.8	23.4	11%
Classroom	.68	42.4	45.0	6%
Classroom	.68	28.3	29.1	3%
Office	.61	38.3	38.5	1%
Electrical Power Laboratory	.12	42.5	45.5	7%
Office	.74	49.4	43.0	15%
Office	.65	42.5	41.3	3%
Office	.83	25.7	29.5	13%
Office	.62	50.9	52.2	2%

The above data show a field check of the interflection method of calculating illumination for various sizes and types of rooms.

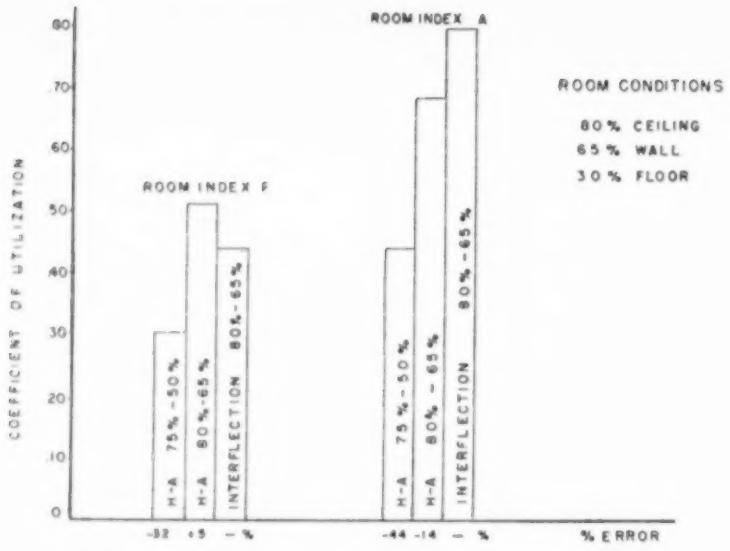


Figure 4. A comparison between the Harrison-Anderson method and interflection for a relatively small room and a large room.

consistently more accurate than the standards used today.

Fig. 4 shows a comparison between the Harrison-Anderson method and interflection. The maximum size room was assumed to be 200 feet by 120 feet with a 9-foot ceiling which gave a room index A. The smallest practical room for this type of equipment was assumed to be 12 feet by 24 feet with a 10-foot ceiling as recommended by manufacturers of luminaires of this type. The Harrison-Anderson method, if corrections are not made, is from 32 to 44 per cent low, while if this method is employed properly the coefficients of utilization compare rather closely for average size rooms. The Harrison-Anderson method seems to be more accurate in a small room while the interflection method seems more accurate in larger rooms. Since this type of lighting is employed mostly in average and large rooms the interflection method seems to be quite satisfactory for the luminous indirect luminaires.

Summary

There are at least three factors which contribute to inaccurate illumination calculations for luminous indirect luminaires. The accumulation of these three factors causes a sizeable error in calculations unless compensation is made. Low coefficients of utilization, combined with maintenance factors which are sometimes too conservative and the fact that present day tables do not go to the higher reflectances of ceilings and walls, all contribute to make an error of 20 to 40 per cent in the resulting illumination calculation. By the use of the interflection method, accurate coefficients of utilization can be obtained.

References

1. *I.E.S. Lighting Handbook*, Second Edition. Illuminating Engineering Society, New York, 1952.
2. Jones, J. R., and Neidhart, J. J.: "Coefficients of Utilization for Luminaires with Concentrating Distributions," ILLUMINATING ENGINEERING, Vol. XLVI, p. 601 (1951).
3. Moon, P., and Spencer, D. E.: "Lighting Design." Addison-Wesley Press, Inc., 1948.

1953 National Technical Conference

Decide now to attend the I.E.S. 1953 National Technical Conference in New York City, this September 14-17. A wide range of applications and the latest in lighting developments will be presented in the four days of technical sessions. The Papers Committee has some 35 papers in the making along with a special session on Light and Vision by internationally famous authorities.

For the ladies and delegates, outside of session hours, the Conference Committee will have information on every possible phase of entertainment in New York; special arrangements will be made for groups to visit the United Nations, see radio and TV broadcasts, attend Broadway "hit" productions, or take the boat trip around Manhattan Island. There may even be a World Series.

INSTALLATION AT LINCOLN PARK ZOO, CHICAGO, ILLINOIS.

Lighting a Zoo Bird Cage

LIGHTING OBJECTIVE: To illuminate an aviary of rare birds for viewing by the general public and television broadcasting.

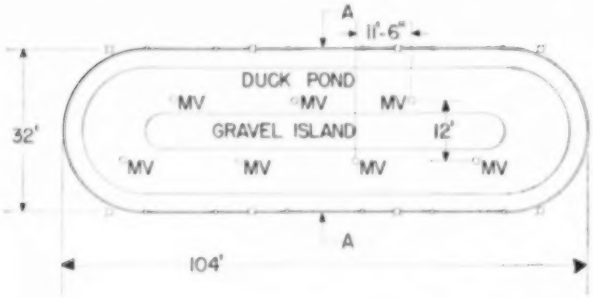
GENERAL INFORMATION: The problem here was to maintain a fairly even distribution of light in the 3000 square foot area from the bottom of the cage up to one-third of the distance from its top (lower two-thirds of cage). Since the public moves on all sides of the cage and the luminaires could not be located within the cage, it was necessary to locate them above it. The brilliant colorings of the birds displayed necessitated excellent color rendition.

INSTALLATION: The cage interior is illuminated to 21 footcandles by eight Holophane #645 high bay luminaires containing 18,000-lumen 400-watt color corrected J-H1 mercury vapor lamps arranged as shown on the following page. The semi-direct luminaires provide some ceiling background brightness.

(over)

A.I.A. File No. 31f

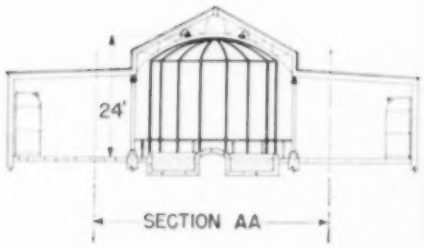
Lighting a Zoo Bird Cage (continued)



Symbols

°MV Holophane luminaire Cat. #645 with 400-watt mercury J-H1 lamp

R.L.M. type luminaire with 300-watt incandescent lamp



Lighting data submitted by Francis Wyatt, Chicago Park District, 425 East 14th Blvd., Chicago as an illustration of good lighting practice and to aid in the design of similar installations.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

New Formula for Room Index

By C. L. CROUCH and EVE FREYER

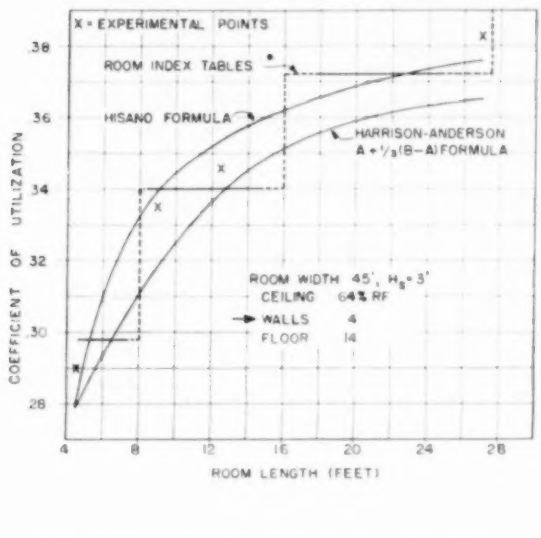
This material is based on a paper prepared in 1949 for the I.E.S. Lighting Design Practice Committee. The modified Hisano equation developed therein was adopted by that Committee and appears in the Second Edition of the *I.E.S. Lighting Handbook*.

THIRTY-ODD YEARS ago Harrison and Anderson[1,2] introduced their notable concept of room index and coefficients of utilization in what is now known as the Lumen Method of calculation. This system was developed from a series of illumination tests in rooms of various sizes. The method has served well through the empirical relationships developed.

The percentage of light output which arrives at the working plane depends upon the room proportions (room index): a tall narrow room results in much of the light being reflected back and forth and lost between the walls before arriving at the useful point, and a lower ceiling in a large room results in the maximum amount of light on the work. Harrison and Andersoon found good formulas for direct and indirect lighting in square rooms. They were not able to arrive at satisfactory ones for rectangular rooms. However, they did find a suitable arrangement of combining coefficients of utilization for square rooms, one having the dimension of the width of the rectangular room and one having the dimension of the length of the room in question. The relationship of $a + \frac{1}{3}(b - a)$ appeared to fit the experimental data quite well; a is the coefficient of utilization for the small square room and b is the coefficient for the large square room.

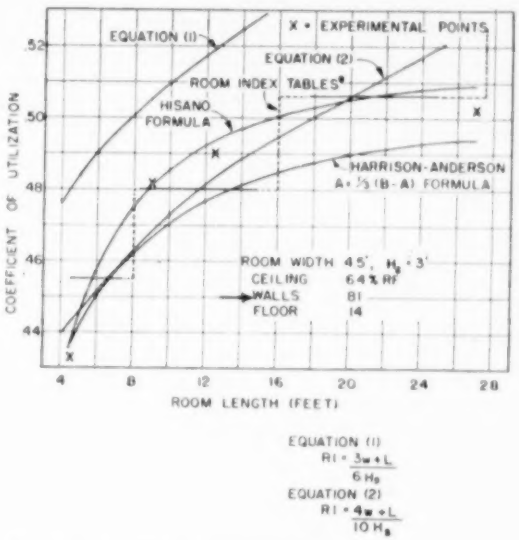
Since then, both in this country and abroad, considerable study[4-10] has been devoted to suitable formulas for room index of rectangular rooms. Apparently independently, two investigators (Margoulis,[6] France, 1928; and Hisano,[8] Japan, 1936) working on opposite sides of the globe arrived at the concept of using a harmonic mean of the room

Technical Director and Assistant to Technical Director, respectively, Illuminating Engineering Society, headquarters office, New York, N. Y.



* INDICES FOR (ROOM DIMENSIONS MULTIPLIED BY 4) TAKEN FROM 1921 G.E. BULLETIN 41.

Figure 1. Comparison of coefficients of utilization from tests, room index calculations and tables. Porcelain-enameled steel bowl reflectors. *Black walls.* (Broken line portions of the step curves represent conditions between values given in the room index tables.)



*INDICES FOR (ROOM DIMENSIONS MULTIPLIED BY 4) TAKEN FROM 1921 G.E. BULLETIN 41.

Figur 2. Comparison of coefficients of utilization from tests, room index calculations and tables. Porcelain-enameled steel bowl reflectors. *White walls.* (Broken line portions of the step curves represent conditions between values given in the room index tables.)

TABLE I.—Comparative Coefficient of Utilization Values For Square and Rectangular Rooms as Found By Test and by Calculation Methods.*

Ceiling height 7 ft. Test plane 3 ft. from floor. Lamps mounted 3 ft. above test plane. Outlets spaced 4.5 ft. x 4.5 ft. Ceiling 64 per cent Floor 14 per cent reflection factor.

Steel Bowl Reflector

Wall Color		Room Dimensions (feet) 4.5x4.5 (1x1)	4.5x9 (1x2)	4.5x13.5 (1x3)	4.5x27.0 (1x6)
Black (4%)	Test	29.0	33.5	34.6	38.3
	Method A	27.9	35.6	39.8	48.6
	Difference	−1.1	+2.1	+5.2	+10.3
	Method B	27.9	33.9	36.9	40.9
	Difference	−1.1	+0.4	+2.3	+2.6
	Method C	27.9	31.8	33.9	36.5
	Difference	−1.1	−1.7	−0.7	−1.8
	Hisano Method	27.9	34.0	35.3	37.6
	Difference	−1.1	+0.5	+0.7	−0.7
Modified Hisano Room Index		(.75)	(1.0)	(1.12)	(1.29)
White (81%)	Test	43.3	48.2	49.0	50.2
	Method A	43.6	50.2	52.5	58.0
	Difference	+0.3	+2.0	+3.5	+7.8
	Method B	43.6	48.1	50.0	52.3
	Difference	+0.3	−0.1	+1.0	+2.1
	Method C	43.6	46.6	47.8	49.4
	Difference	+0.3	−1.6	−1.2	−0.8
	Hisano Method	43.6	48.0	49.4	50.9
	Difference	+0.3	−0.2	+0.4	+0.7

Method A — Coefficient for rectangular room taken to be the same as for a square room whose side is the average of the dimensions of the rectangular room.

Method B — Coefficient for rectangular room taken as the average of the coefficients for square rooms of the long and narrow dimensions respectively.

Method C — Coefficient for rectangular room taken as coefficient for square room of narrow dimension plus one-third of difference between this value and the coefficient for a square room of the long dimension.

Hisano Method — Room Index $= \dfrac{lw}{h_x\,(l+w)}$ (direct lighting).

*Test values and those for Methods A, B, and C taken from Table I, "Coefficients of Utilization" by Harrison and Anderson, *Trans. I.E.S.*, Vol. XV, p. 105 (1920).

dimensions for the equivalent square room which would have the same coefficient of utilization. This seems a logical answer since one would assume a "mean" of some kind. Harrison and Anderson tried an arithmetical mean of the width and length and an arithmetical mean of the coefficients of utilization based upon square rooms having dimensions corresponding to the width and length.

Hisano (ILLUMINATING ENGINEERING, Vol. XLI, No. 3, March 1946, p. 232) not only calculated the distribution of flux from various surfaces of the room but checked the calculations through test. He found that the distribution was practically independent of ratio of $\dfrac{\text{length}}{\text{width}}$ but followed very closely the function $\dfrac{\text{height (width + length)}}{2 \text{ width} \times \text{length}}$ in which $\dfrac{2 \text{ width} \times \text{length}}{\text{width + length}}$ is the harmonic mean of width and length. Thus, the $\dfrac{\text{height}}{\left(\begin{matrix}\text{harmonic mean of}\\ \text{width and length}\end{matrix}\right)}$ governs the distribution of flux and therefore the coefficient of utilization.

Hisano found that the effect of the height of the light source above the working plane was very critical. Therefore, for direct, semi-direct and general diffusing lighting it is necessary to consider the height of the lighting unit above the work, and for semi-indirect and indirect lighting the height of the ceiling above the work.

Since the Harrison-Anderson tables of coefficients of utilization are based upon both experimental data and square rooms, it is easy to utilize the Hisano formula to convert a rectangular room into an "equivalent square room" and thereby find the appropriate coefficient of utilization. However, Harrison and Anderson used the inverse ratio of $\dfrac{\text{width}}{\left(\begin{matrix}2 \times \text{height above}\\ \text{working plane}\end{matrix}\right)}$ for room index (direct lighting of square rooms. Converting the Hisano formula into the Harrison-Anderson form of room index the formulas become as follows:

For *Direct, Semi-Direct and General Diffusing Lighting*

$$RI = \frac{lw}{h_x\,(l+w)}$$

where h_x = height of luminaire above working plane.

For *Indirect and Semi-indirect Lighting*

$$RI = \frac{3\,lw}{2\,h_c\,(l+w)}$$

where h_c = height of ceiling above working plane.

It is interesting to check the accuracy of these new equations against experimental data. Table I of the Harrison-Anderson paper, "Coefficients of Utilization," *Trans. I.E.S.*, 1920, lists the experimental results found in a series of four rooms whose width and mounting height remain constant and the length increases. The results of three methods of determining coefficients of utilization and the variations from test results are shown. Table I is a copy of a part of this table with the addition of the modified Hisano method shown. It is noted that there is a closer agreement using the new formulas for room index. This is shown graphically in Figs. 1 and 2 where it is also interesting to see the comparison of results obtained by use of tables of room index.[3] Fig. 2 shows also two other equations proposed at one time.

Since the above series of four rooms is limited in range of room index (.75 to 1.29)* a check was made of the test rooms recorded in the earlier Har-

*Room index was expressed by Harrison-Anderson in numerical terms giving an idea of room ratio of width to height. Recently letters have been substituted in Coefficient Tables where A = 5, B = 4, C = 3, D = 2.5, E = 2.0, F = 1.5, G = 1.25, H = 1.0, I = .8, J = .6.

TABLE II.—Comparative Coefficient of Utilization Values for Square and Rectangular Rooms As Found by Test and by Calculation Methods.
Reflection Factors: Ceiling 60 per cent, Walls 80 per cent, Floor 14 per cent.

	Direct (Steel Bowl Reflector)				Indirect (Silvered Glass Reflector)			
	Test[1]	Method C[2]	Hisano[3]	Modified Hisano Room Index[3]	Test[1]	Method C[2]	Hisano[3]	Modified Hisano Room Index[3]
Room A 13.5 x 13.5 $h_s = 8.5$, $h_c = 11$	47	45.2	45.2	(0.79)	26	25.0	25.0	(0.92)
Room B 13.5 x 13.5 $h_s = 6.5$, $h_c = 9$	48	48.2	48.2	(1.04)	28	26.6	26.6	(1.13)
Room C 13.5 x 27 $h_s = 4.33$, $h_c = 6$	55	54.6	55.2	(2.07)	33	32.2	32.6	(2.25)
Room D 13.5 x 27 $h_s = 2.17$, $h_c = 3$	60	58.8	59.7	(4.15)	37	36.4	37.1	(4.50)
Room E 13.5 x 27 $h_s = 6.5$, $h_c = 9$	54	50.6	51.3	(1.38)	30	28.6	29.5	(1.50)

[1] ±1 error in reading curves. Data taken from Figs. 10 through 14, "Illumination Efficiencies as Determined in an Experimental Room," by Harrison and Anderson, *Trans. I.E.S.*, Vol. XI, pp. 75-77 (1916).

[2] Coefficient of Utilization $= a + \frac{1}{5}(b - a)$.

[3] Room Index (direct lighting) $= \dfrac{lw}{h_s(l + w)}$.

Room Index (indirect lighting) $= \dfrac{3lw}{2h_c(l + w)}$.

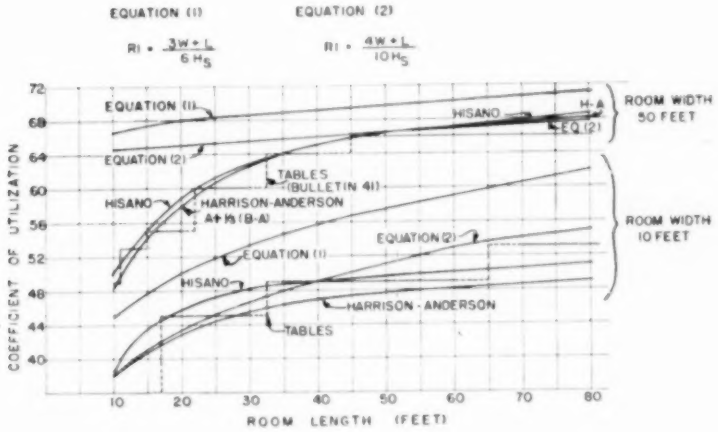


Figure 3. Comparison of coefficients of utilization from room index tables and calculations. RLM dome luminaires mounted eight feet above working plane. Reflection factors: ceiling 50 per cent, walls 50 per cent.

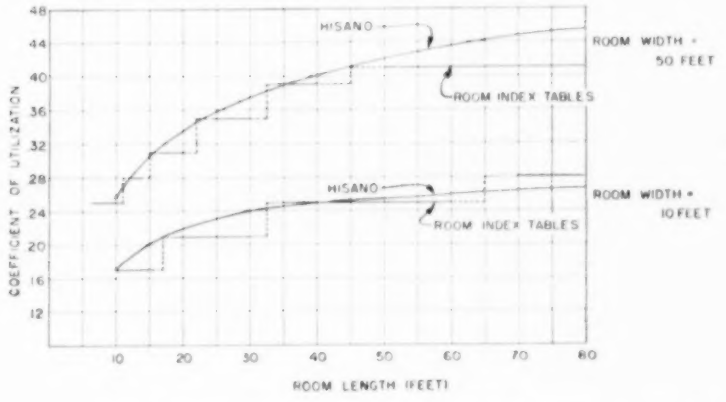


Figure 4. Comparison of coefficients of utilization from room index tables and calculations using modified Hisano equation. Silvered bowl indirect luminaires mounted eight feet above working plane. Reflection factors: ceiling 75 per cent, walls, 50 per cent.

rison-Anderson paper, "Illumination Efficiencies as Determined in an Experimental Room," *Trans. I.E.S.*, 1916, and the results for both direct and indirect lighting are shown for room indexes ranging from .79 to 4.5. See Table II.

To show results using these equations for a series of small and large rooms, Figs. 3 and 4 have been prepared showing a comparison of modified Hisano results with the Harrison-Anderson $a + \frac{1}{3}(b - a)$ concept as well as results obtained by use of two other equations and the original room index tables,[3] upon which all subsequent tables have been based.

Conclusions

Formulas for room index based upon Hisano's[8] and Margoulis'[6] work produce more accurate results in coefficients of utilization and provide a rational system based upon the functional concept of the harmonic mean of a rectangular room's width and length.

Bibliography

1. Harrison, W. and Anderson, E. A.: "Illumination Efficiencies as Determined in an Experimental Room," *Trans. I.E.S.*, Vol. XI (1916), p. 67.

2. Harrison, W. and Anderson, E. A.: "Coefficients of Utilization," *Trans. I.E.S.*, Vol. XV (1920), p. 97.

3. Anderson, E. A.: "Illumination Design Data," General Electric Co., Engineering Bulletin #41, Jan. 15, 1921.

4. Cobu, M. and Dourgnon, J.: "Le Coefficient d'Utilisation d'un Appareil d'Eclairage, Placé dans un Espace Clos," *Revue Générale de l'Electricité*, Vol. 21 (1927), p. 531.

5. Dourgnon, J.: "Nouvelle Méthode de Prédétermination des Coefficients d'Utilisation dans les Projets d'Eclairage d'Espaces Clos," *Revue Générale de l'Electricité*, Vol. 23 (1928), p. 271.

6. Margoulis, W.: "Etude Nomographique pour la Détermination des Coefficients d'Utilisation dans les Projets d'Eclairage," *Revue Générale de l'Electricité*, Vol. 24 (1928), p. 439.

7. Moon, Parry: *The Scientific Basis of Illuminating Engineering*, McGraw-Hill, 1936, p. 349.

8. Hisano, K.: "Light Flux Distribution in a Rectangular Parallelepiped and Its Simplifyng Scale," ILLUMINATING ENGINEERING, Vol. XLI, No. 3 (1946), p. 232.

9. Zijl, H.: "Efficiencies of Lighting Installations," *Philips Tech. Rev.*, Vol. 7 (1942), p. 97.

10. Dourgnon, J. and Cadiergues, R.: "Sur l'Application de l'Equation de Fredholm à l'Etude des Problèmes d'Eclairage et de Chauffage," *Revue Générale de l'Electricité*, Vol. 58 (1949), p. 229.

Numerical Room Ratios

By WILLARD ALLPHIN

DEMANDS for greater accuracy in calculations by the lumen method lead to a re-study of the Room Index factor. The *I.E.S. Lighting Handbook*, Edition II, page 9-2, says:

> Room index is generally obtained from Table 9-I, but the following formulas may be used where more precise utilization values are desired. Intermediate numerical room ratios necessitate interpolations in the utilization tables. For direct, semi-direct, and general diffuse distributions,
>
> $$\text{Numerical room ratio} = \frac{\text{Width} \times \text{length}}{\text{Mounting height above work plane (width + length)}}$$
>
> For semi-indirect and indirect distributions,
>
> $$\text{Numerical room ratio} = \frac{3\,(\text{Width} \times \text{length})}{2 \times \text{ceiling height above work plane (width + length)}}$$

These ratios have been translated into letters of the alphabet in accordance with the table at the bottom of handbook page 9-5, where each letter represents a range of values.

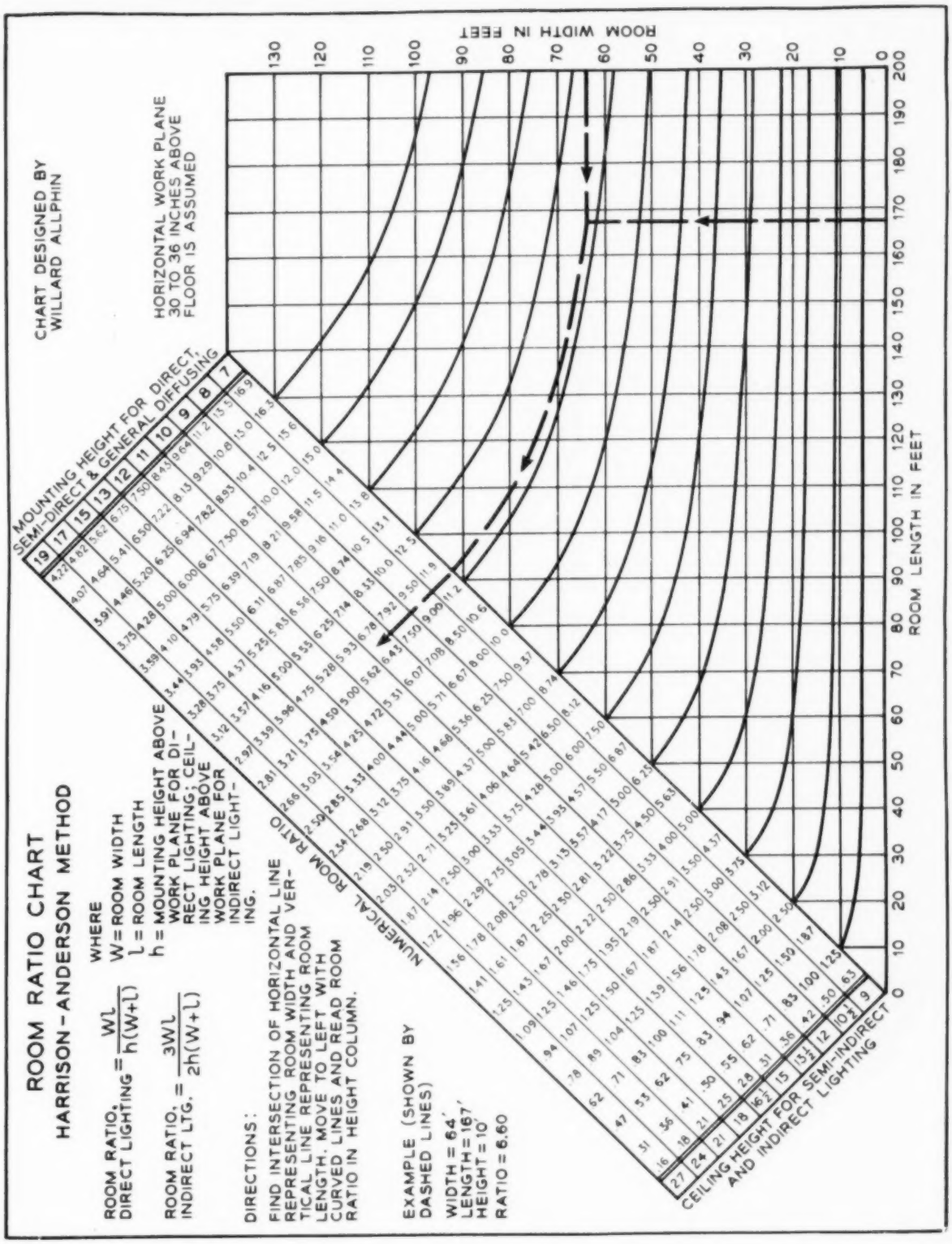
In order to be able to interpolate in tables of coefficients of utilization, it would be necessary to return to the use of the more precise numerical values. However, use of the formulas has a considerable nuisance value, particularly to anyone not trained in the use of a slide rule. On the other hand, to list the data in tables would require a great deal of space. There would need to be a table of room width vs. room length for each ceiling or mounting height considered.

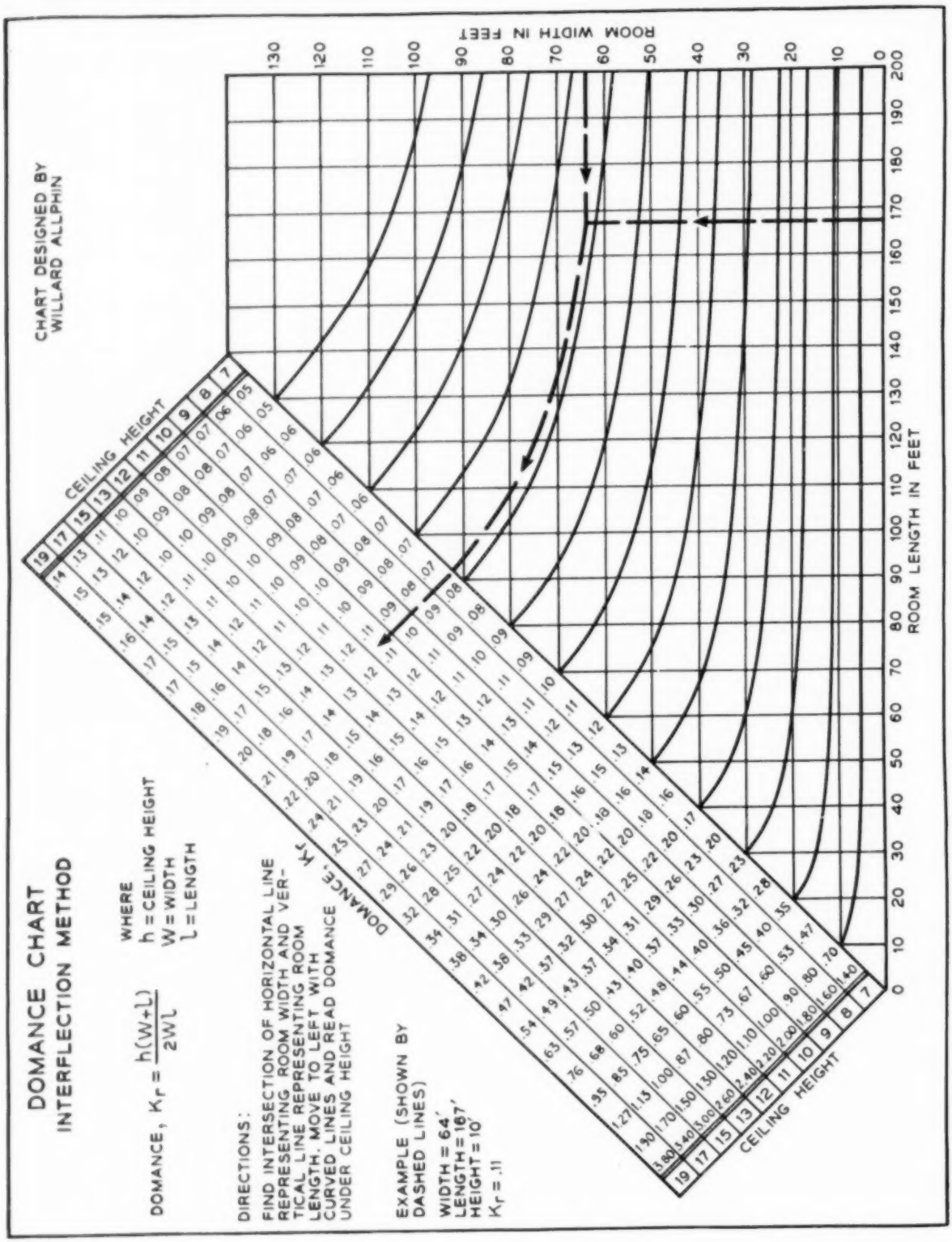
With these points in mind, a new type of chart has been devised which presents a great deal of information in a small space by combining graphs with a table.

Since the formula for "Domance" in the Interflection Method is, except for the constants, the reciprocal of the room ratio formulas, it can be treated in the same way.

The two charts offered here will be useful only when coefficient of utilization tables are supplied with numerical room ratios or Domance values. This will permit interpolation to any degree of accuracy justified by the other factors involved.

AUTHOR: Sylvania Electric Products Inc., Salem, Mass.


ROOM RATIO CHART
HARRISON-ANDERSON METHOD
ROOM RATIO; DIRECT LIGHTING = Wl / h(W+l)
ROOM RATIO; INDIRECT LTG. = 3Wl / 2h(W+l)
WHERE
W = ROOM WIDTH
l = ROOM LENGTH
h = MOUNTING HEIGHT ABOVE WORK PLANE FOR DIRECT LIGHTING; CEILING HEIGHT ABOVE WORK PLANE FOR INDIRECT LIGHTING.
DIRECTIONS:
FIND INTERSECTION OF HORIZONTAL LINE REPRESENTING ROOM WIDTH AND VERTICAL LINE REPRESENTING ROOM LENGTH. MOVE TO LEFT WITH CURVED LINES AND READ ROOM RATIO IN HEIGHT COLUMN.
EXAMPLE (SHOWN BY DASHED LINES)
WIDTH = 64'
LENGTH = 167'
HEIGHT = 10'
RATIO = 6.60
CHART DESIGNED BY WILLARD ALLPHIN
HORIZONTAL WORK PLANE 30 TO 36 INCHES ABOVE FLOOR IS ASSUMED
MOUNTING HEIGHT FOR DIRECT, SEMI-DIRECT & GENERAL DIFFUSING
NUMERICAL ROOM RATIO
CEILING HEIGHT FOR SEMI-INDIRECT AND INDIRECT LIGHTING
ROOM WIDTH IN FEET
ROOM LENGTH IN FEET


DOMANCE CHART
INTERFLECTION METHOD
DOMANCE, $K_r = \frac{h(W+L)}{2WL}$
WHERE
h = CEILING HEIGHT
W = WIDTH
L = LENGTH
DIRECTIONS:
FIND INTERSECTION OF HORIZONTAL LINE REPRESENTING ROOM WIDTH AND VERTICAL LINE REPRESENTING ROOM LENGTH. MOVE TO LEFT WITH CURVED LINES AND READ DOMANCE UNDER CEILING HEIGHT
EXAMPLE (SHOWN BY DASHED LINES)
WIDTH = 64'
LENGTH = 167'
HEIGHT = 10'
K_r = .11
CHART DESIGNED BY WILLARD ALLPHIN
ROOM WIDTH IN FEET
ROOM LENGTH IN FEET
CEILING HEIGHT
DOMANCE, K_r
CEILING HEIGHT

Are We Confusing "Eyes" with "Vision"?

By DARELL BOYD HARMON

EVEN IF it were possible to set a footcandle level by international law, preliminary to clearing the way for illuminating engineers to study the more important subject of brightness and its effects, it is doubtful that the concentrated effort of the entire illuminating engineering fraternity could settle the subject of brightness until it has been appraised in its proper value.

Actually, the physiological mechanisms involved in seeing convince me that the flux density at the retina necessary for efficient visual performance varies with the brightness pattern existing in the surroundings of any task; so, until we can pin down the brightness story, we cannot solve the footcandle one. The brightness problem has always been regarded by the illuminating engineer as a problem of glare, discomfort, or some other factor that interferes with recognition of task details. In reality, brightness pattern interference with recognition of detail is only a secondary part of the brightness story, and if the true brightness problem was solved, the factors related to recognition of detail would automatically be solved as well.

Our present difficulty in trying to define lighting standards is our failure to recognize the fact that there are two distinct physiological mechanisms involved in vision, both of which are related to lighting design. Up to now, the illuminating engineer has completely ignored one of these mechanisms, although any serious study of visual physiology would demonstrate that it is the primary and most significant one in the visual process. This mechanism is the body-balancing and visual-centering mechanism which operates largely through the stimulation of the total retina, and its needs must be satisfied through brightness control before any true determination of the quantity of light for central field recognition can be made. The less attention that is paid to visual needs for posturing and centering — the more complex and difficult it becomes to solve the problem of lighting needs for central field recognition. The reason for this is that the need for central light energy goes up as peripheral contrast goes up, in order to stimulate the metabolic shifts or postural-motor changes necessary to off-set the adverse impulses of the brightness pattern which interfere with the central operations of performance of the task.

To perform any task, whether it is to be done by a machine or a human being, there must be some base from which to operate. This base must be adequately anchored with gravity; the base must be organized to provide proper support for all the moving operations that are to take place in production or in performing a task; and supporting mechanisms and moving mechanisms must be aligned or centered so that all the moving operations can produce the most acceptable product and do it with a minimum of waste, both in terms of waste of energy and of production materials, and in terms of damage to the machine itself. All of these operations must be accomplished with least drag or inertia, or with least energy or effort, so that a maximum amount of the input energy will be available for productive output.

Establishing an adequate base with gravity, and proper alignment of supporting structures and of moving parts (such as eyes and hands), and the organization of this base effort and alignment in a semi-flexible machine such as the human body, is a function of the light gradient over the total visual field. Whether all of this is done properly with least effort so that there is a maximum of physiologic and other resources available for the purposeful part of the task, depends upon the way the total brightness pattern is organized over the entire visual field, not just over the central area. The more unbalanced this brightness pattern is as projected over the total retina, the more effort it takes to stay in balance with the task; the more misalignment there is introduced between body parts; and, the less energy and physiologic equipment there is available for the performance of the purposeful task.

This needed brightness pattern cannot be determined solely in terms of brightness or contrast interference with recognition. Brightness values and relationships that are obtained by research based on recognition and visibility standards (or on any other standard exclusively related to central field vision) are inadequate. The reason for this is that *much of the innervation, or nervous circuiting, leading from the periphery of the retina does not*

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Sept. 8-12, 1952, Chicago, Ill.
AUTHOR: Consulting Educationist, Austin, Texas.

go to the visual recognition centers of the brain at all. These leads go directly to the body posturing mechanisms. The remainder of the leads which do go to visual recognition areas of the brain, go there in summation only, and then only when mixed in an undifferentiated manner with nervous impulses coming from the posturing muscles of the body and from sense organs related to other energy organizations in the environment. Consequently, no brightness values for performance efficiency can really be determined until experiments are set up in terms of the way the periphery of the retina is organized, and measurements then are made in terms of motor outcomes and not visibility outcomes. This is well illustrated in a recent study of position and manner of working in typewriting conducted jointly by the Neurological Clinic of the University of Oslo and the Department of Human Anatomy at Oxford.

The more interference we have in posture-motor areas due to erratic brightness patterns, the more energy — such as light — it will take centrally to provide a static-balancing offset for the tensions produced by bad peripheral light distribution. Anyone with an engineering education will recognize that static balance of this type is actually added and unnecessary inertia which cannot lead to economic productive output. These added stresses cost the human machine too much in wear and tear, and in wasted energy, and defective production, no matter how many thousands of footcandles can be demonstrated to produce "efficiencies" in recognition.

Recent advances in both the physiology of vision and the physiology of learning show that meaningful seeing is the product of experience gained through efficient and economic body-balancing and direction of movement. These advances also show that visual recognition and oral or comparable identification alone are not productive of meaningful seeing. Merely to be able to verbalize a word that is recognized does not indicate, by any stretch of the imagination, that the individual is necessarily learning the word; reacting to the word in an acceptable manner; or, is producing efficiently in relation to the word — no matter how many footcandles can be demonstrated to accelerate the recognition and the accompanying verbalization. Even accurate manual manipulation of objects in relation to detail identification is neither an accurate nor an adequate evaluation of the effect of lighting. Such manipulation can actually fall in the same class as verbalization tasks.

Another thing that recent advances in physiology is showing us is that if adequate, accurate, and economic body balance can be established with a task, the very process of coming to balance and center with the task induces visual accommodation through feed-back. In other words, if the brightness pattern is adequate to allow a person to center freely with the task to be performed (while that person is also free of other physical restraint), the process of coming to that centering automatically produces a first-order focusing of the eyes. When this is accomplished, then footcandles come into play to induce any vernier adjustments of accommodation that may be necessary to induce recognition of some parts of the task detail which are smaller than standard for the general lighting level.

The genuine function of footcandles on the task is to produce the final adjustments of focusing that may be necessary for recognition of fine detail after the brightness pattern has accomplished its work in bringing the body into proper relationship with the task, and has also organized the body so as to provide adequate support for the movements needed in performing the task.

Our approach in the past to establishing illumination values has really been backward. Central field illumination levels are variable functions both of the task and of the brightness contrast pattern in the total visual field. While it is possible through central field lighting alone (meaning by that the lighting which affects the area from the fovea outward to the paramacular border where rods and cones merge) to apparently produce visual efficiency if we pile on the footcandles and adjust only those brightnesses which seem to wash out or interfere with the identification of the "image," the results we obtain are accomplished through an organic dissociation resulting in a terrific ultimate expense to the organism. Such an approach produces an effect very much like trying to take a picture with a heavy view camera, while focusing the lens with the vernier mechanism alone — and not extending the bellows — and at the same time holding the camera in both hands rather than mounting it on a tripod. It can be done, but after a couple attempts the operator quits photography!

The product of adverse stresses produced by lighting designed in keeping with our traditional approach to illumination standards are not reflected by "visual fatigue," blink rate change, or similar tests and evaluations, immediately observable to subjects or testers. The damages show over a longer time in adverse adaptations of body structure or growth, or through detrimental metabolic shifts, or through ineffective performance, learning, or attitude. As one noted ophthalmologist has so well put it: "No one — yes, *no one* — has ever been able to really prove that the human eye can be damaged by poor lighting in an occupational or school surrounding." Where the real clue to adverse lighting effects can be found is in the *atypical* visual (non-eye) signs and symptoms of continued

body stress in performing visually-centered tasks. For example, the Oslo-Oxford Study referred to earlier showed the stress of bad lighting reflected in excessive activity in the dorsal musculature.

Whether you view it in terms of the figure-ground relationships as they are stated by the Gestalt psychologists, or the dynamic mechanics point of view which I take, the problem of lighting standards cannot be solved without a simultaneous study of the functions of peripheral and central mechanisms of vision in relation to light.

The lighting engineers' pre-occupation with the recognition of detail and visibility, and certain vision specialists' descriptions of seeing in terms of reading or recognition, does not explain the "how" of meaningful seeing and visually-centered performance in relation to light distribution patterns. The physiologic mechanisms referred to here are described in detail in all the standard reference works on visual physiology. Duke-Elder, for example, devotes over 300 pages to such descriptions in Volume I of his Text-Book of Ophthalmology. However, too often they are dismissed by the lighting engineer and the "visual researcher" concerned with task lighting, as being "insignificant," "primitive," or too complex to understand. As a consequence, they describe the eyeball as if it was all of vision, separate and apart from the human being, and as if vision operated independently of all the other operations of the body. And, they do this description in terms of "bench" optics, which serious visual research for the last fifty years has demonstrated could not be true in human vision by any stretch of the imagination.

Until lighting engineers begin thinking of vision in terms of total, living, acting, learning, adapting, finely-built and well designed human mechanisms, and not in terms of the "dead-house pathology" of the eye anatomist, the lighting engineer will seldom learn more about standards of lighting. A disservice to seeing human beings has been the perpetuation of variations of the old "camera" theory of vision by the lighting industry; its closing its mental eyes and ears to the vast body of knowledge that research has piled up on vision; and, its continued documentation of errors by turning to "eye men" who don't know any more about vision than their questioners do.

Why don't illuminating engineers get the information on vision that they should have for basing illumination standards when they turn to the ophthalmologist or the non-medical refractionist? Did you ever refer a school child to an ophthalmologist or a non-medical refractionist, after that child had been shown to have some kind of visual problem in the classroom by standardized and accepted vision screening tests, only to have that child given eye examinations under a cycloplegic or by other means, and then have the child sent back with the statement "there is nothing wrong with this child's eyes"? *I have!* Not once, but a good many thousand times in my health department days. And the doctor was correct in his statement — "there is nothing wrong with this child's *eyes*." But that did not mean the child was free of difficulties of vision and visual-centered performance.

It meant literally what the doctor said — there was not detectable pathology of the "eyes," and the optical mechanism operated sufficiently well to project an adequate organization of a light pattern in the visual field back to the light receptors in the retina; and the needed nervous connections between retina and identification centers in the brain (together with those identification centers), worked satisfactorily enough to demonstrate both a monocular and binocular acuity needed to resolve certain standard contrast differences in standard test situations. *But that is all the doctor meant.* His specialty is limited to "eyes," their structure and pathologies, and their physiology as it is limited to the eyes' contribution, as a detector, in resolving contrast differences in the central field. He is not concerned with visually-centered performance, meaningful seeing, visual learning, and visually related body-mechanics — and all the rest of the fields that contribute to understanding meaningful vision and its relation to lighting.

No self-respecting ophthalmologist claims these areas are parts of his practice. These areas are the fields of the physiologist, the psychologist, and the psycho-physicist, and similar researchers. We have just been going to the wrong specialists for our vision information on which to base illumination standards because we have confused "eyes" with "vision."

NOTE: The technical points concerning visual dynamics, developed and illustrated at the Conference presentation by slides and demonstrations, cannot be set forth in this text, because audience participation is needed.

DISCUSSION

H. RICHARD BLACKWELL*: Dr. Harmon contends that the response of the human organism to patterns of light involves the whole organism, rather than merely the eyes. There is little doubt that there is no mode of response of the human organism which is entirely independent of any other. Hence, we must agree that light patterns will influence all modes of response *to some extent*. The question I have concerns the *extent* to which patterns of light influence other modes of response than the sensory and oculomotor mechanisms of the visual system. I find that Dr. Harmon's account of the extent of influence of patterns of light on the postural responses of the human organism brings to

*Vision Research Laboratory, University of Michigan, Ann Arbor, Mich.

mind the spectacle of an insect responding to light stimuli with an heliotropic response. I am sure that such a comparison is not intended by Dr. Harmon. It does seem to me, however, that Dr. Harmon has put his case too strongly. Humans do not respond in the gross, undifferentiated manner of insects to any stimulus, certainly not to light patterns. A high degree of differentiation of response is the special characteristic of the human. Of course, differentiation depends upon maturation and experience. Thus, differentiation increases with age. The adult human is very completely differentiated. In my opinion, differentiation is relatively complete in children of school age. Thus, I believe that the primary effects of patterns of light are upon the sensory and oculomotor response mechanisms of the visual system. Dr. Harmon refers specifically to the usefulness of patterns of light in providing frames of visual reference for the organism through postural responses. I believe it is entirely apparent that frames of visual reference are developed from sensory and kinaesthetic experience. These frames of reference apparently become firmly established at an early age. Subsequent organization of visual space is not appreciably dependent upon kinaesthetic cues. Dr. Harmon's contention that patterns of light elicit bodily orientations and that these in turn provide the cues for the organization of visual space seems to me to deny the human's ability to develop direct and efficient mechanisms for dealing with the physical world. Let us agree that we can never consider the eyes as functioning entirely in isolation of all other bodily functions, but let us realize that the primary effects of light are upon the sensory and oculomotor mechanisms of the visual system.

R. L. Biesele, Jr.*: The author of the paper has restated here his belief, first stated before our Society some eight years ago, that the response of an individual to any visual field or visual task is a total response which is the net result of all the stimuli to which he is being subjected, including stimuli other than visual. This appears reasonable, and it is unfortunate that the author is not yet in a position to supply experimental evidence showing either qualitatively or quantitatively just what some of these effects are.

Certainly any person working in the field of light and vision should be able to cite examples of the effects on vision of stimuli other than visual, and it should not be too difficult to develop experimental procedures to determine the effects. As an example, one of my children, while in the first grade, was given a "routine" eye test with the Snellen chart. The test indicated him to be seriously myopic. A similar test performed in the office of an ophthalmologist indicated presbyopia. A thorough examination, with drugs administered to relax the eye muscles, indicated the child's eyes to be quite normal. The muscular tensions induced by the strange new situations, coupled possibly with inadvertent suggestion from the persons who administered the tests, caused serious deviations from normal visual performance.

This incident serves to illustrate several important points which must be considered in any research program which involves vision. First, it is exceedingly dangerous to generalize broadly on limited or non-existent experimental evidence. Second, the experiment must be carefully designed to eliminate the effects of extraneous stimuli, including psychological stimuli introduced by suggestions from the person conducting the experiment. Third, data obtained from tests where such care has not been exercised must be viewed with a healthy suspicion, if not disregarded altogether. Fourth, it is quite essential that the data obtained from even good procedures be analyzed carefully, since it is rather easy in experimentation on humans to read into the data what one wanted to find.

The fourth point may explain some of the cleavages among the psychologists with which I have become familiar during the many years I have been in contact with college faculties.

In fact, in the field of psychology, it is quite difficult to be sure just who is who, and who knows what.

It is unfortunate that practically all the past research on light and vision has been conducted on young adults, with some data extending to older eyes. My work in school lighting has made me painfully aware of the fact that in spite of all the self-appointed experts we have in school lighting, educational psychology, child development, and the like, there has been practically no experimental work on the visual performance of school age children. The Illuminating Engineering Society could perform no higher service than to initiate and encourage experimentation to fill this serious void in our knowledge of light and vision.

Walter Sturrock*: In this paper Dr. Harmon has emphasized the importance of peripheral vision as an adjunct to central vision, and he recommends that the illuminating engineer more fully consider peripheral vision as affected by the brightness of the surround. He seems to feel that there has been a lack of this in preparing the American Standard Practice for School Lighting. I want to assure Dr. Harmon that the engineer has not overlooked this matter. In fact, Table I of the School Lighting Practice gives a list of recommended limits of brightness ratios for the schoolroom. It is recognized that one of the greatest needs is, as Dr. Harmon points out, that of education and I would add that this is greatly needed for architects, interior decorators, and others who are responsible for room interior finishes which affect brightness distributions.

Many researches and investigations have been made to determine comfortable brightness ratios between the visual task and its surround. In an attempt to rationalize some of these researches for practical application by the engineer, Harrison and Meaker have given numerical ratings to lighting systems. Their paper as published in Illuminating Engineering in February 1947, considers all the contributing factors of brightness from an actual installation of specified equipment within an interior of known dimensions. From their rating system, it is only necessary to decide from experience the numerical rating which represents the limits of comfort for a given task and then specify a lighting system having a rating under this value.

It is difficult for me to interpret Dr. Harmon's recommendations. It would, I am sure be very helpful to the engineer if he could rationalize them in a form for use in our Recommended Practices as he suggests.

*Formerly with Southern Methodist University, Dallas, Texas; Now at the Toff Corporation, Dallas, Texas.

*General Electric Co., Nela Park, Cleveland, Ohio.

Photo courtesy The Austin Company

Figure 1. The strength of a nation lies in its power of production. High levels of quality illumination aid in speeding up production in defense of our country and in maintaining high standards of living.

Cost and Comfort Appraisal of Industrial Lighting Systems

By GEORGE J. TAYLOR
R. D. BRADLEY

Industrial seeing tasks have become more critical with speeded production, closer tolerances, the need for greater accuracy. Lighting recommendations for industrial areas must now include specifications for lighter surfaces, and luminaire design characteristics whch provide a high quality of *illumination*. An attempt is made in this paper to evaluate industrial luminaires in relation to economics and comfort in industrial application.

THE PRINCIPLES behind, and requirements for, quality of illumination in industrial areas have been expounded by leading illuminating engineers at numerous I.E.S. and other meetings, for many months, from coast to coast. That quality in an industrial lighting system is as essential as for offices is now a concept conceded by all. Actually, the steps to quality are simple. 1. Provide an adequate level of illumination for a given visual task. 2. Lighten all surfaces—ceiling, walls, floor, bench tops and machinery in colors as light as practicable for the area involved. 3. More —much more, consideration must be given to improved shielding of light sources and a greater upward component of light.

Luminaire Analysis

To further aid in the application of quality factors to industrial lighting installations, an analysis was made of 19 industrial luminaires, appraising their characteristics in relation to comfort of seeing, economics and maintenance. A summary of this analysis is given in Table I.

Types of luminaires included in the analysis are for regular industrial applications, are all-metal, sturdily and strongly constructed, using channels to house ballasts and lampholders, with detachable closed end all-white all-porcelain reflectors. These features are strongly advocated for factory areas where heavy machinery and dirty atmospheric conditions require the most sturdy finishes and construction available.

Luminaire Types Analyzed

The comparative analysis of fluorescent luminaires is divided into three categories:

(1) GROUP I — Solid top reflectors with all light directed downward.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, Sept. 8-12, 1952, Chicago, Ill.
AUTHORS: Day-Brite Lighting, Inc., New York and St. Louis offices respectively.

TABLE I—Comparison of Industrial Lighting Systems

Luminaires equipped with all-white, all-porcelain enamel reflectors

Room Size: 60' x 120' | Luminaires: 10' above floor | Ceiling: 14' high | Illumination: 50 footcandles maintained | 4000 operating hours per year | Power at 1½c kwh

Luminaire Classification	Group I								Group II								Group III		
Type Luminaire	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	3.40	2.85	2.75	2.40	2.85	2.40	3.40	2.40	3.40	2.85	2.75	2.40	2.85	2.40	3.40	2.40	2.75	2.75	2.40
General Data																			
No. lamps per section	6-40	4-85	2-75	4-40	4-85	4-40	6-40	4-40	6-40	4-85	2-75	4-40	4-85	4-40	6-40	4-40	2-75	2-75	2-40
Luminaire Shielding*	14°x2°	14°x2°	14°x0°	14°x2°	25°x28°	28°x2°	26°x28°	26°x28°	13°x2°	14°x2°	14°x0°	13°x2°	25°x28°	27°x2°	26°x28°	26°x28°	35°x12°	35°x24°	35°x3°
Luminaire distribution																			
90°-180° (uplight)	0%	0%	0%	0%	0%	0%	0%	0%	9%	10%	10%	10%	13%	12%	11%	14%	44%	47%	30%
0°-90° (downlight)	100%	100%	100%	100%	100%	100%	100%	100%	91%	90%	90%	90%	87%	88%	89%	86%	56%	53%	70%
Overall efficiency	77.0%	78.5%	79.0%	78.0%	73.1%	71.0%	63.8%	67.2%	77.2%	83.2%	81.4%	82.0%	72.5%	70.5%	64.4%	69.1%	81.2%	81.0%	79.5%
Maintenance factor	.65	.65	.65	.65	.60	.65	.60	.60	.70	.70	.70	.70	.65	.70	.65	.65	.70	.70	.70
Coefficient of utilization																			
Room reflectances** 75/50	.70	.73	.72	.72	.68	.65	.60	.62	.66	.73	.70	.72	.68	.63	.58	.61	.63	.62	.65
" " 50/30	.67	.68	.68	.68	.65	.62	.57	.60	.64	.68	.65	.67	.59	.58	.53	.56	.53	.52	.57
" " 30/30	.66	.67	.67	.67	.64	.61	.56	.59	.62	.66	.63	.65	.57	.56	.52	.54	.48	.46	.54
" " 30/10	.65	.66	.66	.65	.62	.60	.55	.58	.60	.65	.61	.63	.56	.55	.50	.52	.46	.44	.52
Number luminaire sections																			
Room reflectances 75/50	58	41	80	84	48	93	78	105	55	39	77	78	48	69	69	99	85	86	172
" " 50/30	60	44	85	89	50	98	77	109	58	42	83	84	52	97	75	108	101	103	196
" " 30/30	61	45	86	91	51	99	78	111	60	43	85	87	54	100	77	112	112	116	207
" " 30/10	62	46	88	93	53	101	80	112	62	44	88	89	55	102	80	116	116	122	215
Watts per sq. ft.																			
Room Reflectances 75/50	2.23	2.30	1.99	2.22	2.69	2.46	2.88	2.78	2.18	2.16	1.92	2.06	2.67	2.36	2.74	2.62	2.12	2.13	2.28
" " 50/30	2.38	2.47	2.11	2.35	2.80	2.57	3.03	2.89	2.30	2.30	2.07	2.22	2.86	2.56	3.02	2.85	2.51	2.56	2.60
" " 30/30	2.42	2.53	2.14	2.39	2.87	2.61	3.08	2.93	2.38	2.39	2.11	2.28	2.97	2.60	3.04	2.96	2.78	2.88	2.75
" " 30/10	2.46	2.56	2.19	2.46	2.95	2.66	3.13	2.98	2.46	2.41	2.19	2.35	3.05	2.69	3.17	3.06	2.88	3.03	2.85
Cost Data (75/50)																			
First cost including lamps	$4,569	$4,625	$4,937	$5,625	$6,112	$6,474	$6,554	$8,189	$4,335	$4,395	$4,752	$5,222	$6,107	$6,197	$6,197	$7,719	$6,171	$6,527	$6,818
Per cent (of Type 1)	100%	101%	108%	123%	134%	142%	144%	180%	95%	97%	104%	115%	134%	136%	136%	169%	135%	143%	149%
Annual operating cost	$1,664	$1,671	$1,693	$1,751	$2,079	$1,976	$2,263	$2,426	$1,571	$1,559	$1,611	$1,605	$2,039	$1,873	$2,118	$2,238	$1,903	$1,961	$1,900
Per cent (of Type 1)	100%	100%	102%	105%	125%	119%	136%	147%	95%	94%	97%	97%	122%	113%	127%	135%	114%	118%	114%
Annual maintenance cost	$102.30	$72.35	$99.30	$115.05	$141.20	$139.85	$215.30	$259.20	$82.50	$55.40	$77.10	$87.75	$115.15	$109.80	$172.50	$301.00	$116.30	$126.25	$114.45
Per cent (of Type 1)	100%	71%	97%	112%	138%	137%	210%	253%	81%	54%	75%	86%	112%	107%	168%	196%	114%	122%	112%
Cost per sq. ft.																			
First cost	$.63	$.64	$.69	$.78	$.85	$.90	$.91	$1.14	$.60	$.61	$.66	$.73	$.85	$.86	$.86	$1.07	$.86	$.91	$.95
Annual operating cost	$.23	$.23	$.24	$.24	$.29	$.27	$.31	$.34	$.22	$.22	$.22	$.22	$.28	$.26	$.29	$.31	$.26	$.27	$.26
Comfort Data (75/50)																			
Glare factors																			
Crosswise	234	157	140	146	152	75	138	88	121	112	98	97	77	47	68	48	16	14	8
Lengthwise	276	152	125	130	119	92	122	79	131	140	95	94	62	56	64	41	21	15	31

*Luminaire shielding: First figure denotes crosswise shielding; second figure lengthwise shielding

**Room reflectance: First figure denotes ceiling reflectance; second figure wall reflectance

(2) GROUP II—Slotted top reflectors with 10 to 15 per cent uplight and the remaining light directed downward.

(3) GROUP III—Open top reflectors with 30 to 50 per cent uplight and the remaining directed downward.

In the grouping of the solid top reflectors are (see Table I):

(1) Luminaires for two and three 40-watt T-12 fluorescent lamps.

a. Normal type (Types 1 and 4)
b. Longitudinal baffle (Type 6)
c. Eggcrate louver (Types 7 and 8)

These luminaires are designed for nominal 8-foot channels and 4-foot reflectors.

(2) Luminaires for two 85-watt T-17 fluorescent lamps.

a. Normal type (Type 2)
b. Eggcrate louver (Type 5)

These luminaires are designed for nominal 10-foot channels and 5-foot reflectors.

(3) Luminaires for two 75-watt T-12 slimline lamps.

Normal type (Type 3)

These luminaires are designed for nominal 8-foot channels and 8-foot reflectors.

In the grouping of the slotted top reflectors with 10 to 15 per cent uplight are (see Table I):

(1) Luminaires for two and three 40-watt T-12 fluorescent lamps.

a. Normal type (Types 9 and 12)
b. Longitudinal baffle (Type 14)
c. Eggcrate louver (Types 15 and 16)

These luminaires are designed for nominal 8-foot channels and 4-foot reflectors.

(2) Luminaires for two 85-watt T-17 fluorescent lamps.

a. Normal type (Type 10)
b. Eggcrate louver (Type 13)

These luminaires are designed for nominal 10-foot channels and 5-foot reflectors.

(3) Luminaires for two 75-watt T-12 slimline lamps.

Normal type (Type 11)

These luminaires are designed for nominal 8-foot channels and 8-foot reflectors.

The grouping of the open top reflectors with 30 to 50 per cent uplight are presently in the stages of development. They are (see Table I):

(1) Luminaires for two 40-watt T-12 fluorescent lamps without cross louvers (Type 19).

These luminaires are being designed for nominal 4-foot channels and 4-foot reflectors. Development is also underway for designs using 8-foot channels and 8-foot reflectors for slimline lamps.

(2) Luminaires for two 75-watt T-12 fluorescent lamps with cross louvers (Types 17 and 18).

These luminaires are designed for nominal 8-foot channels and 8-foot reflectors.

Room Conditions

In order to analyze each luminaire type in relation to comfort and economics, a typical factory area representing average construction features was assumed. The room size was chosen to give a "room index" of "A," or 60 feet by 120 feet. Luminaires are mounted 10 feet above the floor. The height of the ceiling is considered to be 14 feet and of concrete slab construction.

To study and compare the various types of luminaires under varied conditions, four factory finishes with reflection factors as follows were considered:

Finish	Ceiling	Walls
1.	75%	50%
2.	50%	30%
3.	30%	30%
4.	30%	10%

While all sorts of conditions for room finishes are still prevalent in many industrial interiors, it is not the intent to encourage the use of low reflectances of room finishes. Later in the paper it will be shown that low reflectances are undesirable for many reasons. It may be stated here that it is desirable to follow room finish reflectances as specified by the I.E.S. Recommended Practice of Industrial Lighting. This also includes such surfaces as machines, bench tops and floors.

Lighting Calculations

Illumination computations were made for the 19 types of lighting systems using the lumen method to provide 50 footcandles maintained. The conditions and general factors applying to these computations are shown in Table I. An operating rate of 4000 hours per year was used in determining annual operating costs with the power rate of 1½¢ per kwh.

Average published values for lumen output and life of fluorescent and slimline lamps were used in the illumination calculations as follows:

Lamp	Ballast	Cool White (Lumens)	Average Life (Hours)
40-Watt 48" T-12	Tulamp	2300	7500
85-Watt 60" T-17	Tulamp	4600	7500
75-Watt 96" T-12	Series	4800	6000

The assignment of maintenance factors for various luminaires favors slotted and open top reflectors over solid top reflectors. Tests have been conducted showing that a draft action takes place through reflector openings which reduces the rate of depreciation of light due to dust and dirt accumulation. It is possible that completely open top reflectors with high upward light components may

have some advantage over slotted top reflectors with lower upward light. However, this condition has not been established and maintenance factors for both these classifications were assigned the same values for similar type luminaires.

Cost Data

Computed costs are based upon an in-service level of 50 footcandles. Branch circuit wiring costs are included in the comparative cost results shown in Table I. These costs are based upon two 3-phase, 4-wire distribution centers in the 60-ft. x 120-ft. room and 120-volt circuiting to continuous rows of luminaires for the various lighting systems. Included in the wiring costs are the cost and installation of lighting panel boards, branch circuit wiring in conduit to luminaire channels and wiring connections to each luminaire.

The installation of luminaires in their proper location includes cost and installation of mounting anchorage points in the ceiling from which luminaires and suspension members are supported. These costs and the cost of luminaires are based upon normal competitive bidding for large factory areas through union electrical contractor purchasing materials and equipment through an authorized electrical distributor.

The installation costs of luminaires are based upon an unoccupied room area. Such costs may be materially higher if machines or other equipment are in place making it difficult or impossible to use and move scaffolding in the room.

All luminaire prices are based on the use of metal clad "push type" sockets including the 85-watt units.

The net cost of fluorescent and slimline lamps is based upon a 30 per cent discount from list prices to which is added an amount of 10.4 per cent of list prices for excise tax. Amortization is given at 10 per cent of total luminaire costs (excluding lamps).

Appraisal of Lighting Systems

Comparisons of first costs for the 19 types of luminaires analyzed for the four room finishes 75/50, 50/30, 30/30 and 30/10 are shown in Table I. However, the *first cost* and *operating cost* of a lighting system is by no means the criterion upon which a lighting installation is selected. Other important factors beside cost may be the determining factor in the final selection of the system to use. These factors, not necessarily in order of their importance, may be listed as follows:

1. Comfort—quality of illumination
2. Appearance—aesthetic effect
3. Maintenance—lasting qualities
4. First cost—initial investment
5. Operating cost—annual investment

Whatever weight or importance is assigned to any of the above factors for any valid or special reason will determine the type of lighting system to use. If high comfort and good overall room appearance is desired, System 18 might be considered. If low maintenance is coupled with reasonably good comfort, System 14 may be the answer. If cost is a consideration with a fair degree of comfort, System 11 might be considered. The point is, the five factors listed above do have a direct bearing on the final selection of a lighting system.

Comfort

The comfort, or quality, of the illumination provided by a lighting system takes into consideration:

Brightness and area of the source
Luminaire light distribution and proper brightness ratios and contrasts
Proper shielding of the source
Overall room conditions, such as proper brightness patterns and ratios between visually adjacent surfaces, as well as between work, and work surfaces and other room areas or background.

To correlate all these features into one comprehensible condition to produce the desired result in terms of comfort has always been a difficult thing to achieve, even by the experienced lighting engineer.

In appraising the comfort of the lighting systems analyzed here, the Harrison-Meaker method of glare rating has been used. It was felt that this method provided a relatively valid figure of merit from the standpoint of comfort. It applies widely to varying types of luminaires under given room conditions, and is as simple to apply as the lumen method in computing footcandles.

In calculating the "glare factors" the Harrison-Meaker method takes into account the basic elements of room conditions in terms of reflection factors of: ceiling—75 per cent, walls—50 per cent and work surfaces—15 per cent.

Glare factor values for the 19 lighting systems are shown in Table I. Only one room size, ceiling height and room finish condition is given for the sake of simplicity. This study, however, indicates the importance of carefully selecting a lighting system if comfort of seeing is to be obtained.

In a paper titled "Glare Factors and Their Significance" (G. E. Review, August 1947) Harrison-Meaker state that "from observation in factories it may be predicted that glare factors in the range of 50 to 75 will probably be found to represent generally acceptable comfort conditions for industrial type applications." Based on this comfort range it is observed that highest comfort is obtained with Group III luminaires having 30 to 50 per cent upward light component. Attention again is called to the fact that all room finishes must conform to con-

ditions previously given to obtain the best results of quality lighting and "brightness engineering" to achieve comfort of seeing. For instance, if machinery or floors or bench tops are dark in color (of low reflectance value) while ceilings are bright by comparison, discomfort may result.

Next in line in consideration of employee comfort are Group II luminaires with 10 to 15 per cent upward light component. Systems 14 and 15 fall well within the comfort range of glare factors for industrial type applications. So does System 16 but for comparable range of comfort the costs are high. System 13 fares well from the standpoint of comfort and cost. It is interesting to note that all these systems have better than normal shielding.

It will be seen that glare factors are about the same for System 11 (two 75-watt slimline) as System 12 (two 40-watt fluorescent). This close proximity of results will apply to slimline vs. fluorescent in other instances also. For example, System 14 with two 40-watt fluorescent as shown would give reasonably close results with the same type of luminaire for two 75-watt slimline.

Group I luminaires have glare factors out of the normal comfort range in the higher footcandle brackets and for this reason they are not as suitable for industrial applications where comfort is a criterion.

The glare factor values shown in Table I are computed for a lighting level of 50 footcandles. Since comfort is a measure of projected and accumulated glare sources (luminaires and ceiling brightness) its range in terms of glare factors will increase with higher footcandle levels and decrease with lower levels. So in determining a lighting system for comfort it must first be established what level of illumination is required for the specific seeing task. If "ordinary seeing tasks" are involved where 30 foot candles are recommended glare factors for System 14 would be around 35 crosswise and 40 lengthwise as compared with 47 and 56 respectively when 50 footcandles are required for a "difficult or critical seeing task." At 60 footcandles the respective values would be around 53 and 63. Similar comparative reasoning applies to other systems presented in Table I.

Attention is called to the fact that glare factors for any given level of illumination decrease when mounting heights of luminaires increase. Conversely, glare factors increase as luminaire mounting heights are lowered. Also as room sizes become smaller glare factors become lower. The converse is true, with larger rooms glare factors increase.

Maintenance

In the analysis, maintenance costs are based principally upon the type and number of luminaires used in the installation. The costs include only *cleaning or washing costs* and *labor to replace burned out lamps.* The two 85-watt units (System 2, Group I, and System 10, Group II) are the cheapest to maintain in their respective groups. Next in line in maintenance economy are the two 75-watt units (System 3, Group I, and System 11, Group II).

It should be pointed out that *maintenance* is more than just the cost relation indicated above. Construction of a luminaire is of vital importance. In factories, machinery and operating equipment is of a heavy duty type to withstand hard production usage. The strength and durability of industrial luminaires, as discussed in this paper, should match the design of shop machinery for good and efficient performance. Porcelain enamel reflectors with its hard glass-like surface and ease of cleaning has a direct bearing on overall economy. Louvers if used should be designed so that continued cleaning or relamping will not distort their original shape. When cross louvers are required they should be of such design that they do not need straightening every time they are handled. Furthermore, "heavy duty" luminaires will look the same five years or more after they are installed—a matter of some significance in relation to maintenance costs.

Accessory equipments — ballasts, lampholders, starters, etc.—have their part in the picture. Approved parts should always be specified for satisfactory trouble-free service.

First Cost

It is interesting to compare lighting costs of the various lighting systems presented by Groups. For example, three systems are briefly compared with two different room finishes as follows:

	Group I System 6	Group II System 14	Group III System 18
Coef. of Util.			
75/50	.65	.63	.62
30/10	.60	.55	.44
No. 8' Sections			
78/50	93	89	86
30/10	101	102	122
First Cost			
75/50	$6,470	$6,200	$6,530
30/10	$7,030	$7,060	$9,290
Maintenance Cost			
75/50	$140	$110	$126
30/10	$152	$127	$179

In analyzing the above it is to be expected that good room finishes (75/50) have good coefficients of utilization for the three systems shown. The higher the upward component of light the greater the coefficient of utilization suffers when poor room conditions prevail as shown. Since luminaires with open reflector tops have better *maintenance factors* than when tops are closed, the number of

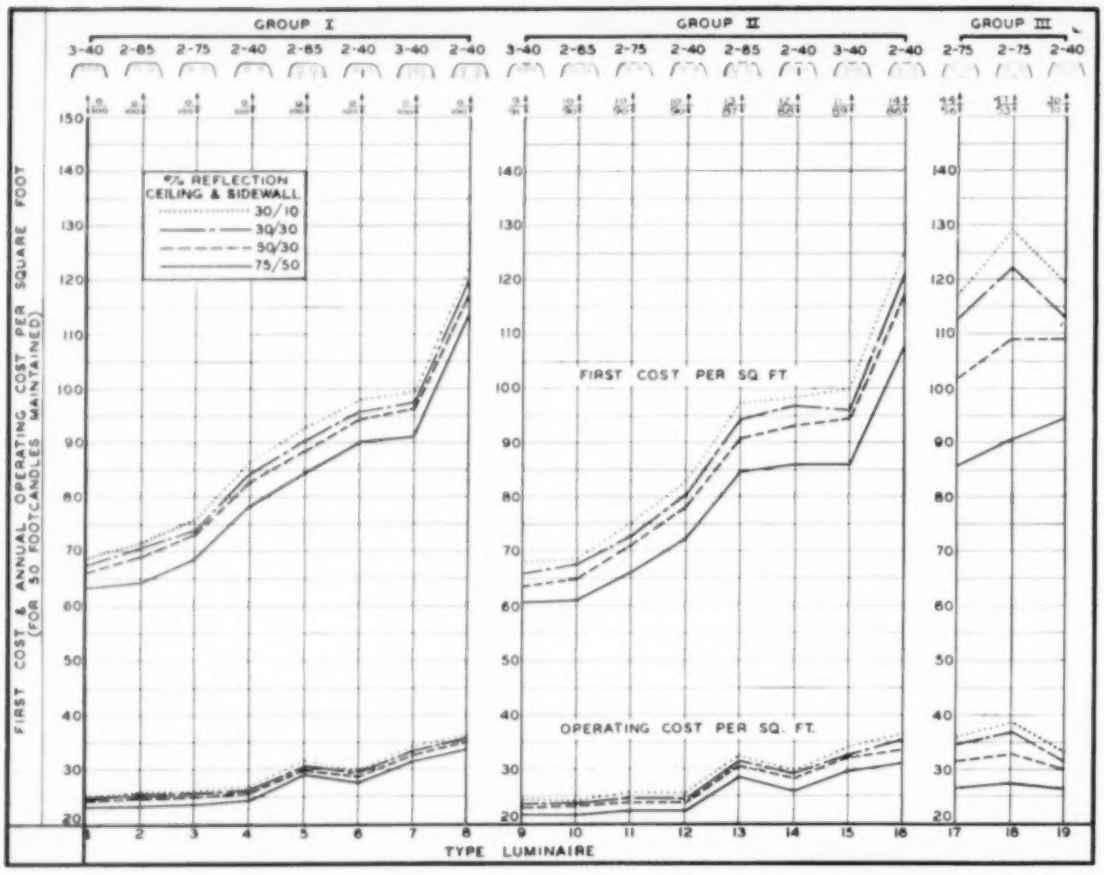


Figure 2. Average costs per square foot for typical industrial type luminaires to produce 50 footcandles (maintained). Lighting cost includes local panel boards and wiring to luminaires.

units required does not increase in proportion with the coefficient of utilization. System 14 with 12 per cent uplight uses fewer luminaires than System 6 for good room finishes and only a slight percentage more for poor room finishes, while System 18 with 47 per cent uplight suffers greatest with a 30/10 room finish. System 14 shows up with lowest first cost of the three systems compared at 75/50. It is much lower in cost than System 18 at 30/10 and reasonably close to System 6. Further study shows System 14 with lowest maintenance costs. This analysis indicates that lighting systems with 10 to 15 per cent uplight are a better buy than systems without any uplight and, of course, such systems provide more comfort for factory workers.

Comparative *first costs* are graphically shown in Fig. 2 for all lighting systems studied in this paper. The data shown are for installed costs per square foot. Dollar values may be obtained by multiplying costs per square foot by 7200 (square feet) which is the size room assumed. For rooms which are much larger in size, the cost per square foot may be slightly lower than for the 60-ft. x 120-ft. room size. Smaller than 60-ft. x 120-ft. room sizes on the other hand would result in higher cost.

Since a paper of this nature is limited in length, only one luminaire for slimline lamps was included in each of Groups I and II. When comparing equivalent two-lamp units of 75-watt slimline and 40-watt fluorescent (System 3 *vs.* 4, Group I and System 11 *vs* 12, Group II) it is seen that 75-watt slimline systems are about 10 per cent lower in first cost than 40-watt fluorescent systems. It is likely that the trend will continue to favor slimline lamps for factory applications. Closed end reflectors were used in the analysis. For open end reflectors (Groups I and II) the first cost values may decrease by approximately 10 per cent.

Operating Cost

The operating cost or upkeep of a lighting system has a direct bearing on lighting economics. Operating costs are graphically presented on a square foot basis in Fig. 2.

A close examination of Fig. 2 will disclose the importance of good room finishes in considering economics with luminaires providing upward light. If the three Systems (6, 14 and 18) used in the above discussion on *first costs* are compared it will be seen that operating costs are reasonably close for a 75/50 room. For a 30/10 room Systems 6 and 14 are approximately the same while there is a very marked increase for System 18. Very often *maintenance costs* are seriously considered in the operation of a lighting system. This takes into account washing of reflectors and labor in replacing lamps. System 14 takes first place for low maintenance costs compared with Systems 6 and 18.

Application of Luminaires

Design characteristics of industrial luminaires have developed progressively, though slowly, toward comfort conditions. The dark green totally-direct incandescent dome reflector was in 1925 supplemented by the Glassteel Diffuser having a small upward component with an all-white porcelain enamel finish. Early fluorescent luminaire standards followed the pattern of cut-off and finish established by incandescent units, but cut-off was later improved by using a "longitudinal" baffle. Next followed designs with a small amount of upward light. Current practice calls for higher upward components of light with white outside reflector finishes and greater shielding.

Luminaires for 100 Footcandles

Levels of 100 footcandles are recommended by the I.E.S. Recommended Practice of Industrial Lighting, for "very difficult" and "most difficult" seeing tasks. For seeing comfort at these levels, luminaires in Group III, with 30 to 50 per cent upward light are essential. Naturally, room conditions must comply for good brightness patterns. Ceilings should be white having a minimum reflectance of 75 per cent; walls 50 per cent; with light finishes on machines, bench tops, floors, etc., in accordance with I.E.S. Recommended Practice.

Luminaires for 50 Footcandles

Where levels of illumination are prescribed at 50 footcandles for "difficult and critical seeing tasks," luminaires of Group III for certain applications may prove desirable. Other applications may find luminaires of Group II satisfactory. The choice between these two groups will depend upon the specific seeing task and the normal viewing angles at which such tasks are viewed. For instance, where prolonged viewing is normally near or above the horizontal line of sight, Group III is suggested. Where the line of sight is substantially below the horizontal, Group II may be suitable.

High reflectance room and equipment finishes are just as important in applications of 50-footcandle systems as for the 100-footcandle bracket. Obviously, economics will have a direct bearing on the selection of the ultimate luminaire chosen for either of the two groups.

Luminaires for 30 Footcandles

Where levels of illumination in the 30-footcandle bracket are prescribed for "ordinary seeing tasks," iluminaires in Group II with 10-15 per cent upward lighting will find their greatest application. While it is desirable to have light colored room and equipment finishes where Group II luminaires are used, it may not always be possible to achieve this goal in factory practice.

Luminaires for Lower Levels

In areas where "easual seeing tasks" are performed, say a 10-footcandle bracket, luminaires in Group I with all downlighting may be permissible. This, however, is based on the fact that at such low levels, luminaires are widely spaced and overhead lighting will result in a "spotty" lighted ceiling. It does not necessarily follow that these luminaires are *most* desirable. Group II luminaires "maintain" better because of the "draft" action afforded by the open slots. The same reasoning may be applied to areas where "rough seeing tasks" are performed in the 5-footcandle bracket.

Supplementary Lighting

Where luminaires are used for supplementary lighting below or slightly above the horizontal line of vision, Group I may be found desirable. However, where luminaires are mounted substantially above the horizontal line of vision for purposes of supplementary lighting, the Group II may be desirable due to better maintained lighting values. There are numerous seeing tasks that require illumination levels from 200 to 1000 footcandles or more. Localized lighting units of varying designs are available for incandescent and fluorescent lamps. They should be applied to supplement general lighting where the higher illumination levels are required at the point of seeing.

Conclusion

For many years industrial lighting has been applied with less attention given to the virtues of comfort than in offices. Yet, many visual tasks are very much more critical and difficult in factories. Industrial luminaires casting all light downward account for dark gloomy ceilings resulting in poor brightness ratios and discomfort.

Much more attention is being given to the general appearance of industrial interiors these days, not only for the sake of pride but as an employee morale builder. Economics is not just a matter of

dollars and cents from the standpoint of installed costs or operating costs. Return on investment is part of the economic story and a very important one. Naturally, plant conditions have a bearing on type of lighting equipment to be installed. If luminaires with high upward light (Group III) are used ceilings must be white and kept white by repainting at proper intervals. Plant operators are aware of the many problems involved in the repainting of large ceiling areas with overhead trusses, pipes, ducts, etc., and on the floor a congestion of machines, all of which must be carefully covered during the process of repainting. Moreover, this repainting cannot be done any old time and certainly not during production hours. Yet, if ceilings are not properly maintianed with Group III (high uplight) luminaires as much as one-third of the light may be lost by absorption should room finishes deteriorate from 75/50 to 30/30. Luminaires in Group II with moderate upward light are affected far less by room finishes and, therefore, are preferred when the conditions mentioned above are a matter of concern to management.

Acknowledgments

The authors are indebted to many people and organizations of wide experience who devoted a great deal of time to supplying information for this paper. Particularly acknowledgment is given to Mr. Richard Osborne, Osborne Electric Company, Electrical Contractors and Engineers, St. Louis, and to Mr. Phelps Meaker, General Electric Lamp Department, Nela Park.

Bibliography

1. Taylor, George J.: "Specification for Production Lighting," ILLUMINATING ENGINEERING, Vol. XLVII, p. 361 (July 1952).
2. Taylor, George J.: "Industry Needs Quality Lighting," *Electrical Construction and Maintenance*, Part I (Jan. 1952), Part II (Feb. 1952).
3. Gilleard, George, and Weibel, William: "Glare Factors—New Guides to Eye Comfort," ILLUMINATING ENGINEERING, Vol. XLVII, No. 3, p. 119 (March 1952).
4. Guth, Sylvester K.: "BCD Brightness Ratings in Lighting Practice," ILLUMINATING ENGINEERING, Vol. XLVII, No. 4, p. 184 (April 1952).
5. "Industrial Lighting Practice," ILLUMINATING ENGINEERING, Vol. XLVI, No. 5, p. 225 (May 1951).
6. Pieper, G. E.: "Relighting a Factory to Present-day Standards," ILLUMINATING ENGINEERING, Vol. XLVI, No. 5, p. 249 (May 1951).
7. Taylor, George J.: "Quality—Our Next Step in Industrial Lighting," ILLUMINATING ENGINEERING, Vol. XLVI, No. 5, p. 257 (May 1951).
8. "Pointers for Proper Maintenance," ILLUMINATING ENGINEERING, Vol. XLVI, No. 5, p. 257 (May 1951).
8. "Pointers for Proper Maintenance," ILLUMINATING ENGINEERING, Vol. XLVI, No. 5, p. 262 (May 1951).
9. Harrison, Ward: "Glare Ratings," ILLUMINATING ENGINEERING, Vol. XL, No. 8, p. 525 (Sept. 1945).
10. Harrison, Ward, and Meaker, Phelps: "Glare Factors and Their Significance," *General Electric Review*, Vol. 50, No. 8, p. 31 (Aug. 1947).
11. Harrison, Ward, and Meaker, Phelps: "Further Data on Glare Ratings," ILLUMINATING ENGINEERING, Vol. XLII, No. 2, p. 153 (Feb. 1947).
12. Meaker, Phelps: "Brightness vs Area in the Glare Factor Formula," ILLUMINATING ENGINEERING, Vol. XLIV, No. 7, p. 401 (July 1949).
13. Evans, Ralph M.: "Psychological Aspects of Color and Illumination," ILLUMINATING ENGINEERING, Vol. XLVI, No. 4, p. 176 (April 1951).
14. Travis, Roland C.; Kennedy, John L.; Mead, Leonard C., and Allphin, Willard: "Muscle Action Potentials as a Measure of Visual Performance Cost," ILLUMINATING ENGINEERING, Vol. XLVI, No. 4, p. 182 (April 1951).
15. Benson, Jr., Benjamin Scott and Church, Eric H.: "The 'X' Factors in Fluorescent Lighting," ILLUMINATING ENGINEERING, Vol. XLVI, No. 2, p. 53 (Feb. 1951).
16. Guth, Sylvester K.: "Comfortable Brightness Relationships for Critical and Casual Seeing," ILLUMINATING ENGINEERING, Vol. XLVI, No. 2, p. 65 (Feb. 1951).
17. Biesele, Jr., R. L.: "Effect of Task-to-Surround Brightness Ratios on Visual Performance," ILLUMINATING ENGINEERING, Vol. XLV, No. 12, p. 733 (Dec. 1950).
18. Egeler, C. E., and Vanden Boom, R. F., "Maintenance of Industrial Lighting," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10, p. 522 (Oct. 1951).
19. Allphin, Willard: "The Cost of Seeing a Critical Industrial Task," ILLUMINATING ENGINEERING, Vol. XLVI, No. 10, p. 530 (Oct. 1951).
20. Benson, Jr., Benjamin S.: "Planned Lighting in Industry Is Production Lighting," ILLUMINATING ENGINEERING, Vol. XLV, No. 5, p. 282 (May 1950).
21. Kahler, W. H.: "Basic Fundamentals Answer to Supplementary Lighting Problems," ILLUMINATING ENGINEERING, Vol. XLV, No. 5, p. 291 (May 1950).
22. "Supplementary Lighting Techniques," ILLUMINATING ENGINEERING, Vol. XLV, No. 3, p. 152 (March 1950).
23. "Lighting for Machining of Small Metal Parts," ILLUMINATING ENGINEERING, Report of the I.E.S. Committee on Lighting, Vol. XLIV, No. 10, p. 615 (Oct. 1949).
24. Gaetjens, A. K.: "A Guide to Realistic Maintenance Factors for Lighting Installations," ILLUMINATING ENGINEERING, Vol. XL, No. 5, p. 307 (May 1945).
25. Luckiesh, Matthew: "Brightness Engineering," ILLUMINATING ENGINEERING, Vol. XXXIX, p. 75 (Feb. 1944).
26. Darley, W. G.: "White Floors," ILLUMINATING ENGINEERING, Vol. XXXIX, No. 2, p. 112 (Feb. 1944).
27. Darley, W. G., and Gaetjens, A. K.: "What Price Industrial Eye Comfort?" ILLUMINATING ENGINEERING, Vol. XXXIX, No. 10, p. 825 (Dec. 1944).
28. Darley, W. G.: "Lighting and War Production," ILLUMINATING ENGINEERING, Vol. XXXVIII, No. 6, p. 307 (June 1943).
29. Gaetjens, A. K.: "Lighting Maintenance in War Industry Plants," ILLUMINATING ENGINEERING, Vol. XXXVII No. 7 p. 403 (July 1942).
30. Harrison, Ward, and Luckiesh, Matthew: "Comfortable Lighting," ILLUMINATING ENGINEERING, Vol. XXXVI, No. 10, p. 1109 (Dec. 1941).
31. Taylor, George J.: "Lighting Large Factory Areas with Fluorescent Lamps," ILLUMINATING ENGINEERING, Vol. XXXVI, No. 10, p. 1414 (Dec. 1941).

DISCUSSION

D. P. CAVERLY*: I wish to congratulate the authors on this paper for a good piece of analysis work. For some time we have needed a cost comparison of certain types of industrial luminaires, and I believe the data given in the charts are a valuable contribution to our industry.

While I have no quarrel with the data presented, I should like to comment on its interpretation as a plea for upward light in industrial areas, because I don't think upward light alone will accomplish what we seek.

The suggestion is made in this paper, as it has been in others, that the quality achieved in office lighting installations is a sort of goal toward which we must work to improve our industrial lighting standards. Yet, good office lighting is not necessarily the result of upward light. There are thousands of excellent office installations wherein the light is 100 per cent downward. Troffers are almost an accepted standard since the old bugaboo of "severe contrast" between luminaire and ceiling has been tried in the balance and found wanting. This is because along with troffer acceptance have come light colored floors, walls and furnishings to reflect light to the ceiling and reduce such contrast.

It is probably true that if we could build our offices around the lighting system, we might not start with troffers.

*Sylvania Electric Products Inc., New York, N. Y.

But things don't work out that way. Low ceilings, sound and air conditioning, maintenance and several other factors indicate recessed lighting equipment as satisfactory from all standpoints, so that direct lighting in offices becomes quite acceptable to us.

To apply this thinking to industrial applications, it seems to me that we should not exclude direct lighting techniques in our enthusiasm for new model luminaires having slotted reflectors or other means of directing various amounts of light upward. There is, in my opinion, a place for both, the type selected to depend entirely upon the characteristics of the industrial area to be illuminated.

Modern industrial plant design demands, in areas where noise is detrimental to quantity and quality of production, that sound-conditioning ceilings be used. Such areas, which are usually air-conditioned too, include machine shops and wherever operating machinery produces distracting noise. The weave room of a textile mill or the assembly room of a watch manufacturing plant are quite different, yet both are typical of this type of manufacturing process.

I feel sure that most of us have seen sound- and air-conditioned industrial applications. They are not at all uncommon and more are being built each day. In them, the ceiling and other structural features usually indicate the use of recessed luminaires such as troffers wherein the light is 100 per cent downward.

I want to repeat that I take no exceptions to the data presented in this paper. Upward light in amounts depending upon the nature of the industrial area is a decided step toward an improved standard of industrial lighting — if it is applied only where it will accomplish the purposes for which such luminaires are designed. The authors recognize this and have mentioned it in their paper. The purpose of my comments is primarily to emphasize the point and to stress also, for the record, that direct lighting will not necessarily become obsolete for industrial plants simply because we seem to have rediscovered that an upward component of light can, under the circumstances, improve the quality of industrial illumination.

CHARLES W. MACY*: I am pleased to note in the Taylor-Bradley paper that the trend in Industrial Lighting is towards "quality" lighting similar to the trend in Office Lighting. It seems to me that it would be wise to keep in mind, when considering Industrial Lighting, the goals of (1) greater production, (2) less rejections through errors, (3) elimination of hazards caused by inadequate lighting and (4) the improvement of the general atmosphere.

As the authors point out, there are many different seeing tasks in industry and many different types of industries. I would like to add that soot and dirt conditions vary considerably in that in some sections of the country where natural gas is the common fuel the maintenance problem is relatively simple as compared with other sections of the country where coal and oil are used for fuel. Again, I would like to point out the difference in electric energy average cost per kilowatt hour. Apparently, few realize that where the average commercial and industrial rate in Northern California, for example, is approximately 1c per kwh, this is simply a dream in the middle west and east where the rates are more likely to be from twice to four times this rate. Actually, what often can be considered a sane standard for much of the country falls considerably short of the accepted standard practice for intensity and quality in lighting where this 1c rate is a fact — simply because the operating costs are so much lower by comparison and the dollar can purchase so much more light per square foot of plant or office space.

The upward component of light in industry of course depends to a great extent upon the type and the height of the ceiling above. However, rare is the industrial area that would not be greatly improved by the introduction and/or maintaining of a white or off-white ceiling and upper walls. Slots or openings in the top of industrial reflectors provide the district advantage of light ceilings, provided the ceiling itself is sufficiently light in color. Naturally this lowers the brightness contrast between the lamps and the ceiling, and minimizes the reflected light pattern which can often be so annoying. For "most difficult seeing tasks" it seems to me that both "higher intensities" and *higher light quality* are important.

As one reads the authors' remarks with regard to the advantages of lighter colors for equipment, backgrounds, and ceilings; and most of us will agree with him; surely we should consider and appreciate the constant changing that is forever going on in our world of progress. Our ancestors did not enjoy the effectiveness and safety of our present day detergents. No wonder such dark surfaces were popular for floors, walls, desk tops, table tops and wherever surfaces were found difficult and costly to keep clean and bright. It is hard to understand the resistance to the lighter colors.

It is most interesting to find the authors drawing attention to the fact that "there are numerous seeing tasks that require illumination levels from 200 to 1000 footcandles or more" and that localized lighting units are available to provide these intensities. Let's go a step further and add that there are lamps now available like the PAR 56 that will provide 25,000 footcandles at a distance of approximately two feet and at a practical equipment and power cost to operate. Welders require that intensity on work in order to see the work through the cobalt glass apertures (in their hoods) before they strike the arc with a rod.

I like this paper for the reason that the author evidently aimed to keep it practical and not deal in conditions difficult to maintain in the field.

Particularly I wish to commend the authors on employing the *Harrison-Meaker Method of Glare Rating in Industrial Lighting* where direct lighting fixtures are commonly used and where the reflected glare that they cause is so often a blessing. There are many instances in industry where specular reflection from metals and surfaces is found highly desirable and useful to the worker. This of course does not hold true in office or classroom lighting.

Lighting fixture maintenance means different things to many different plant supervisors and in different parts of the country. Again, the common fuels used in any area have a large bearing on the frequency of cleanings and enter into the matter of fixture and lamp selections. Aside from this factor we should all keep in mind the following points:

(a) Locating luminaires with the thought of accessibility.
(b) Ease of disassembling and reassembling fixtures.
(c) Strength of materials in fixtures.
(d) Safety from both operating and maintenance standpoints.
(e) Whether or not equipment is portable or subject to adjustment in use.
(f) The proximity to and possible use of hoists, cranes, etc.

It seems to me that greater emphasis should be placed on the fact that industrial lighting is one lighting classifica-

*Pacific Gas & Electric Co., San Francisco, Calif.

tion where lighting improvements can often be closely measured and evaluated by "before and after" studies. I feel sure that most lighting field sales people will agree that there are roughly two ways to light an industrial (or commercial) area.

(1) The quicker sale calls for selling raw light on an intensity basis, using the good old light meter as the only measure. This is of course the cheaper way to *peddle* lighting equipment and always reaps the customer complaints and attendant headaches, loss of costly valuable time and ultimate loss of customer confidence through his dissatisfaction.

(2) The other way calls for both selling and engineering. This way aims directly to fulfill the customer's needs, to bring him complete lighting satisfaction and to gain his confidence and future business.

Again I wish to commend the authors for stressing the great importance of white and light colored paints as a light conserver as a means to less waste and greater efficiency. If we keep our minds on *light;* its production, utilization (with emphasis on quality) and conservation (through light paints, etc.), then we will have used truth in the interests of our customers. Action speaks louder than words and our customers will appreciate first class service and stay with us.

It seems to me that the authors have been indirectly saying these same things when they continually point out methods to conserve *light* and to provide *quality light.*

Whenever we design light that results in public satisfaction, we build public confidence and a lot of future business—a much better and stronger foundation, for that future that is just around the corner.

TAYLOR M. BARR*: The co-authors, Messrs. Taylor and Bradley, have recognized the fact that the cost of an industrial lighting system is only one factor which should be taken under consideration. They have recognized the fact that where maintenance permits the conventional office lighting system may be a solution to lighting problems in many industrial areas. Why shouldn't the reasonably clean industrial area have overall room conditions such as proper brightness patterns and ratios between the adjacent surfaces and other room areas or backgrounds the same as in an office area?

I was interested in their comments that tests have been conducted showing that a draft action takes place through industrial reflectors' open slots which reduces the rate of depreciation of light due to dust and dirt accumulation. It seems to me that further data should be presented covering this subject, not only with the slotted equipment but with the semi-open top reflectors having high upward light components. Possibly a study under varying plant conditions would give us more information on this.

With respect to maintenance, it has been brought to my attention that simple cleaning methods in many cases have not caused undue hardship on the plant maintenance crews. Many plant superintendents look upon this as a necessary expense since they value the amount of illumination that they are using for critical seeing tasks in the plant areas.

The authors have commented briefly on supplementary lighting. They state that under certain conditions Group I luminaires may be found desirable. On many operations where high intensity localized lighting is necessary, projection equipment may be more practically applied.

The authors are to be congratulated on presenting a paper which gives some very definite conclusions aside from the actual cost data and while cost is an important consideration in "sight" conditioning an industrial area, it is only one of many considerations which must be recognized in planning an effective and efficient working area.

FLOYD SELL*: Industrial lighting today is called upon to provide the worker with the means of producing a better product at less cost to the human seeing mechanism and its related parts.

This paper does an excellent job of showing the employer that it is economically sound to install Group II fixtures instead of Group I. The choice between Group II and III is not nearly as well defined because the increased cost of Group III to the employer must be weighed against the intangible item of the cost of seeing for the employee as expressed in glare factors.

In their calculations Messrs. Taylor and Bradley chose maintenance factors of 60 per cent for Group I fixtures while Groups II and III were assessed at 65 per cent and 70 per cent. Our experience indicates that he was conservative in the latter. Several years ago we made a survey of one of our small machine shops equipped with fixtures similar to Type 19. These fixtures and lamps were cleaned each year by a maintenance contractor. A few days before cleaning we measured the illumination at several specified locations and on the day following the cleaning we repeated the procedure. The results showed an increase of only 10 per cent. It is therefore logical to assume that dust and dirt accumulation on lamps and fixtures for a one-year period would reduce the illumination only 10 per cent providing there was no permanent depreciation of the reflecting surface.

These findings prompted us to make further studies of the maintenance benefits of ventilated reflectors. Four luminaires using two 85-watt lamps were installed in an area where acetylene and are welding operations were performed. Two of the group were porcelain enamel of identical size and shape having 14" x 2" shielding. The other two were Alzak aluminum likewise identical in size and shape but having 35" x 3" shielding. One of each type was ventilated. The porcelain enamel had an upward component of 8 per cent while the aluminum was 40 per cent. Approximately 10 months' operation showed the following results in depreciation of the *reflecting surface only* due to the accumulation of atmospheric residue.

		Depreciation
$\frac{8}{92}$	Porcelain Enamel Ventilated	8%
$\frac{0}{100}$	Porcelain Enamel Non-Ventilated	21%
$\frac{40}{60}$	Alzak Aluminum Ventilated	3%
$\frac{0}{100}$	Alzak Aluminum Non-Ventilated	24%

It seems to us therefore that the authors would have been justified in using higher maintenance factors for Groups II and III which would have resulted in an even better economic picture.

E. A. LINSDAY**: This paper combines the too-frequently divorced factors of cost and comfort in industrial lighting systems.

In the past, the comfort of industrial lighting has been seriously limited by the type luminaires available. One of the reasons for this limitation was a general belief that

*Central Hudson Gas & Electric Corp., Poughkeepsie, N. Y.

*Detroit Edison Company, Detroit, Mich.
**General Electric Company, Nela Park, Cleveland, Ohio.

better quality industrial lighting could not be obtained without increasing the problem of maintenance. Tests have shown that reflectors accumulate less dirt when properly ventilated than when not ventilated.

Photometric tests on filament luminaires under identical conditions revealed that a unit with no ventilation dropped to 35 per cent output, while a reflector with a slotted husk had an efficiency of 62 per cent. When clean, the efficiency of both units was approximately 65 per cent. In the units with ventilating holes, the heat developed by the lamp produced sufficient convection currents to carry most of the dirt up through the unit, instead of being deposited on the reflecting surface.

We recently began similar tests on various types of fluorescent luminaire designs in an effort to determine the effect of ventilation, louvers, and other design features on maintenance factors. Although our data are not in completed form at this time, it does appear that properly positioned ventilating holes definitely decrease the accumulation of dirt on reflecting surfaces. The choice of a maintenance factor necessarily assumes a certain frequency of cleaning, as well as the prevalence of dirt in the area. The authors' assumptions concerning these factors would be of interest. In general, however, the relative maintenance factors assigned to the various luminaire types by the authors is basically in agreement with our present test information.

It is gratifying to see again a rather large scale application of glare factors for comfort analysis. Care should be taken not to misinterpret the 50-75 range quoted by the authors. In 1947, industrial lighting then considered somewhat better than average happened to fall in the 50-75 range. Glare factors down to the value of 15 needed in offices are applicable to some kinds of factory work.

The authors show exact values for glare factor. This method, however, is not precise enough to warrant attaching any significance to small differences. A rounding off, such as to the nearest 25 for values above 100, would be wise before drawing conclusions. The authors compare luminaires types 6, 14 and 18. This comparison indicates that the type equipment (luminaire 6) which represented good quality industrial lighting practice only a few years ago has been improved upon both as regards costs and comfort. Either 14 or 18 shows up well with light room finishes.

The economic advantage of slimline 96T12 stands out plainly and tends to explain the present trend toward this lamp for industrial applications.

Another interesting comparison is 14 and 17 (44 per cent upward light)

	Type 14	Type 17
First Cost	136%	135%
Annual Operating Cost	113%	114%
Glare Factors		
Crosswise	47	16
Lengthwise	56	21

With standoff costs and a significant increase in comfort with unit 17, it appears that 44 per cent upward light can be provided as inexpensively as 12 per cent up.

The units analyzed leave an important gap in amount of upward light. The range of 15 per cent to 30 per cent up has been omitted. Perhaps this range would prove to be the best compromise between cost and comfort.

R. L. ZAHOUR*: The authors' paper is very interesting for I can remember, back 25 years ago, how we stressed the importance of painting the upper side walls and ceilings with non glossy white paint in order to re-direct some of the light to the working areas below, and at the same time brighten the upper surface regions to create a contrast favorable for eye-comfort. Then came the Glassteel Diffuser with its slotted top to permit some "up light" for further contrast improvement, and with an enclosing globe to soften the direct glare of the bare, clear glass bulb incandescent lamp. Even in those historic days, the benefits of quality lighting for industrial areas were fully recognized, and in spite of the limited less efficient lighting tools available, efforts were being made to promote improved shielding, to provide some upward component of light, and to use light finishes on walls and ceilings.

In their paper, Messrs. Taylor and Bradley have very forcibly appraised this quality fundamental of industrial lighting, only this time, they had a greater variety of far more efficient lighting tools available for their analysis. While some factories today still have wall and ceiling finishes of 30/30 or even 30/10, there is a growing tendency towards higher reflectances of 75/50. I believe this is the result of efforts to bring surround contrasts within reasonable ratios that will provide eye comfort where recommended higher footcandle levels are installed.

The authors have done a thorough job of exploring the field of industrial areas with 14 foot ceilings where fluorescent lighting is most suitable. However, appraisal analyses are yet to come that will cover high bay areas where mercury vapor luminaires or R-57 type reflector lamps (both mercury and incandescent) are known to be more efficient lighting tools than fluorescent equipment. Such a study should include costs of paint materials and painting labor.

G. P. WAKEFIELD*: Messrs. Taylor and Bradley have completed a masterful paper pertaining to industrial lighting. A paper of this sort requires a tremendous amount of effort. Table I alone represents many long hours of computation and planning.

The authors state that the steps to quality illumination are simple. I believe this is true provided your specifications of quality are based upon, let us say, current industrial practice. If you were to use maximum visibility on the work as an added criteria you then would find the task of providing quality lighting much more complex. This brings up a question of what is quality illumination? How is it measured? What are the standards of quality? This is an appropriate problem for the Society to answer. It is easy to foresee future standards specified for varying industrial tasks. For example: Sheet metal working—Class III quality; paper inspection—Class I quality, etc. It is possible that standards of quality might be applicable to all lighting conditions.

It is going to be difficult for maintenance men to believe that open top reflectors stay cleaner than closed top reflectors. I am wondering if tests show conclusively that this is true in all industrial surrounds.

If open top luminaires provide a visual gain and evidence seems to point in this direction, then maintenance men will not be so likely to make the important decision of choosing the kind of illumination (or luminaires). The point I wish to bring out is that maintenance should not dictate to visibility. I think visibility is of greater importance. We must prove this theory to ourselves and then the public.

Under the authors' "Appraisal of Lighting Systems" five factors are listed: (1) Comfort, (2) Appearance, (3) Maintenance, (4) First Cost, (5) Operating Cost. Do the authors believe visibility at the task will be added sometime in the future?

*Westinghouse Electric Corporation, Bloomfield, N. J.

*F. W. Wakefield Brass Co., Vermilion, Ohio.

LEON T. JOHNSON[1]: This paper by Messrs. Taylor and Bradley is not technological but is, rather, a paper concerning the application of lighting equipment.

In general, regardless of authorship, application papers which appraise on an economic basis the use of several types of luminaires in a specific interior area, as this paper does, all too often are incomplete. This tends to mislead the reader. Also, the limitations, pitfalls, and qualifying conditions which are associated with each study are pointed out to the reader inadequately. The reader is usually left alone with a table or a few curves which show these luminaires (i. e. lighting systems) arranged in some order of economic sequence. There are too few cautionary signals placed before the reader to warn and guide him in his interpretation and application of the data presented in the paper. Thus he is left to his own devices and, unfortunately, he frequently concludes in error. To him, the studies are totally complete, tell the whole story, and apply universally. Fourteen years in the utility lighting field has shown me that these situations obtain with respect to too many of the persons who daily are advising customers on matters of illumination.

To be specific, certain of the lacks which the Taylor-Bradley paper has are enumerated as follows; with these lacks corrected, the paper could be a most useful tool to help men in the field who do customer contact work.

Point No. 1.—Title of Paper is Misleading.

I suggest a different title for this paper—"A Study of Cost and Comfort Appraisals of 19 Industrial Fluorescent Lighting Systems To Provide 50 Ft c of General Illumination in a Factory Area." Such a title is more nearly descriptive of the paper. As I go on, I think you will see why.

Point No. 2.—Certain Economic Factors Are Omitted or Implied.

Certain Maintenance Costs. In the paper, the maintenance costs associated with ballasts, starters, and painting of room surfaces have been omitted. Customers today are giving more real consideration to the cost and nuisance values associated with starter maintenance. In the case of Group III type of luminaires, more frequent painting of room surfaces will be necessary, to maintain a given lighting level properly, than would be the case with Group I type of luminaires. The study should give cognizance to this situation.

Cleaning of Luminaires. The paper implies that all of the considered luminaires are cleaned the same number of times per year. It is conceivable that certain customers will desire to take advantage of the inherent favorable maintenance characteristics of the Group III type of units and clean them less frequently. The effects of this procedure have not been discussed in the paper.

Reflected Glare. Reflected glare has not been considered. None the less, it should be given serious consideration if industrial lighting techniques are to move forward to provide improved visual environments for industrial workers.

Although the preceding omissions and implications may be not of prime importance to the specific case discussed in the paper, they may well become very important points in other instances where the reader will apply the results of the study.

Point No. 3.—The Study Applies Only to a Specific Industrial Situation.

The study given in the paper applies only to a factory when the conditions of room index, mounting height, level of illumination, power costs, wiring costs, amortization, etc., are the same as given in the paper. In the case of another industrial plant, if these conditions differ materially from those stated in the paper, it is reasonable to assume that the results will be different also.

Point No. 4.—The Study Tends To Channelize and Regiment Industrial Lighting Application in the Minds of Readers Who Are Not Competent Engineers.

Studies of the sort presented in this paper tend to channelize and regiment lighting application in two respects—(1) by type of lighting system, and (2) by lighting design technique.

Type of Lighting System. This paper provokes a tendency to reduce several types of lighting to a strict order. Because of this, readers who are not competent engineers will too frequently think for a moment about their particular industrial lighting problem in the light of its similarity to a specific system given in the study and then will select that system of lighting which seems to "fill the bill." Unfortunately, the art of lighting application is not as simple as this. If it were, then there would be need for only one typical analytical study for each field of lighting application and fellows like myself could be replaced with mail boys.

Lighting Design Technique. The paper implies a straightforward layout design, employing conventional continuous run technique. Whereas this situation satisfies the conditions at hand, such would not necessarily be the case under conditions of greatly differing footcandle level or mounting height. For example, for a particular lower level of illumination, I can conceive of consideration being given to 4-foot units on individual outlets as compared to 8-foot units in continuous run installation. Or, how about mercury lighting where mounting heights of 40 feet are encountered? We should not tend to regiment lighting design techniques, but rather should encourage the use of initiative on the part of design engineers. Unless a paper is fully qualified, this situation is apt to occur frequently.

Point No. 5.—Consideration Is Given to More Types of Luminaires Than Should Be Analyzed for the Case at Hand.

I believe that a certain minimum level of illumination and quality of lighting should be pre-assigned by the designing engineer to each lighting job to be laid out, on the basis of the severity of the eye task to be performed. By so doing, certain luminaires should be considered whereas certain others should be precluded. I cannot quite conceive that for an industrial area to be given practical consideration it is necessary to appraise 19 different fixtures. In this paper, such has been the case. Also, a weighing of one system of lighting against another has been suggested on the basis of comparing operating costs vs. comfort appraisals.

To insure a more thorough understanding of my point, consider the school field, which is better known and understood. Do we include in our analysis of conventional classroom lighting fixtures the industrial RLM luminaire? And then do we say that for the conventional fixture we have high cost with low glare factor, but in the case of the RLM we have essentially the reverse situation? I don't think so. Instead, it is the usual practice to consider only that relatively small group of fixtures which will provide on a practicable basis the quantity and quality of illumination that has been deemed the minimum commensurate with the eye tasks performed.

Well, it may seem that I have been most critical of this analytical study. Such has not been meant to be the case

[1] Public Service Gas & Electric Co., Newark, Ohio.

at all. I am not adverse to this or other similar economic studies, as such. In fact, they are very useful tools. I have attempted simply to sharpen the tool so that its usefulness will be increased to those in the field who will use it. However, because of the inherent characteristics of such studies, I believe that when they are to be made available to the public, the author must assume certain professional obligations — the author should see that the paper is titled properly, and that it is documented and qualified in all respects so that the reader with due diligence will not misconstrue the presented data. In this manner, the reader will be made cognizant that the paper is:

(1) A study applicable specifically to only one situation.
(2) Complete to the degree indicated by the author.
(3) A guide to aid in the preparation of a similar study —not to be used per se but to be modified as necessary to fit the customer's actual conditions and situation.

R. W. OSBORN*: This paper is of considerable value to an electrical contractor in providing preliminary estimates as he is often required to do. To the average electrical contractor, this paper will be too technical and will be disregarded. This should not, however, be classed as a weakness of the paper, but rather a weakness of the electrical contractor. The electrical contractor needs to acquaint himself with this sort of activity, as it will tend to raise the standards of the industry.

I am quite certain that the electrical contractor would appreciate more information as to how the cost of the various systems would be affected in the case of 120/240 volt, 3 wire single phase distribution and also some information on cost data, if the 480/277 volt, 3 phase, 4 wire system was to be utilized.

G. GILLEARD**: Two years ago at the Pasadena Technical Conference, Mr. Taylor presented the forerunner of today's paper, "Appraisal of Modern Fluorescent Office Lighting Systems." The previous paper and the paper presented today are exceptional in their economical analysis in that they compare installations for comfort as well as for foot candles. We feel that this recognition of comfort is vitally important in any appraisals of lighting systems.

The appraisal of the nineteen different types of luminaires is based upon a given room size, given room conditions, and a given quantity of illumination. It it realized that in such a comparison a typical area must be used to keep the paper within a reasonable number of pages. I wish to discuss the use of glare factors in industrial areas of all sizes and for any level of illumination from 10 footcandles to 100 footcandles. One chart will illustrate how this information can be made available by the manufacturer so that a comfort evaluation can be obtained as readily as finding a coefficient of utilization. All of the calculations for such a table may be made at the same time the photometric data for the particular luminaire are compiled. An independent test laboratory would calculate the glare factor for the manufacturer as they now calculate coefficients of utilization. Looking at this table, we find that the various room sizes are given and the glare factors for both endwise or crosswise viewing for various mounting heights. Also from the table you can determine whether to run the units lengthwise or crosswise which could not be determined by visual inspection or merely by statement of shielding angles. These glare factors are calculated for 50 footcandles, but the multiplying factors at the bottom of the table can be applied to the value in the table to obtain the glare factor for any given level of illumination.

I disagree with the placing of the three different groups of luminaires in categories determined by footcandle levels —most difficult, 100 footcandles; difficult, 50 footcandles; and ordinary seeing, 30 footcandles. In many industrial areas the task may not be classified "most difficult" but the worker is engaged in a seeing task over a long period of time where 30 footcandles or 50 footcandles with comfortable seeing conditions is most desirable. In these cases where lower levels are provided for economic reasons it is easy to justify recommendations for the best quality illumination.

In support of the above statement, there is one other factor particularly important in industrial application and this is reflected glare. The specular reflections from polished metal surfaces is well known to cause discomfort as well as to reduce efficiency in performing seeing tasks. In addition to using the glare factor as a measure for comfort from direct glare, it is also necessary that careful consideration be given so that reflected glare will be reduced to a minimum. When the image of the light source is reflected from a specular or semi specular surface, objectionable brightness ratios are reduced if the surface also reflects a well illuminated ceiling. The reflection of the ceiling becomes the "surround" or background for the reflection of the source. In most cases it will be found that when an installation is designed for a low glare factor, conditions usually will be provided so that objectionable reflected glare is minimized. Care should be exercised that the brightness of the source blends into the brightness of surroundings.

Room Width	Room Length	Mounting Height Above Floor (Feet) 8½ Units End-wise	8½ Units Cross-wise	10 Units End-wise	10 Units Cross-wise	13 Units End-wise	13 Units Cross-wise
15	20	7	8	....	....	....	....
	30	7	8	....	....	....	....
	40	7	8	....	....	5	6
	60	8	9	....	....	5	6
	80	9	10	....	....	5	6
20	30	7	8	7	8	....	....
	40	7	8	7	8	....	....
	60	8	9	8	9	....	....
	80	9	10	8	9	....	....
	100	9	10	8	10	....	....
30	40	8	9	8	9	7	8
	60	9	10	9	9	7	8
	80	10	12	9	10	....	....
	100	10	12	9	10	9	10
40	40	....	....	8	9	....	....
	60	....	....	9	10	....	....
	80	....	....	9	10	....	....
	100	....	....	10	11	....	....

NOTE: Computation made for initial conditions of a 50 ft c maintained installation and a 75% ceiling reflectance, 50% wall.

Multiplying Factors for Other Footcandle Levels

Footcandles:	10	20	30	40	50	60	80	100
Multiply by:	0.5	0.7	0.8	0.9	1.0	1.1	1.2	1.3

G. M. MARKS*: I would like to thank the authors for what I consider to be a valuable contribution to the subject of industrial lighting. Mr. Taylor's first paper following a very similar analysis has been of invaluable assistance as a

*Osborn Electric Company, Electrical Contractor, St. Louis, Mo.
**Curtis Lighting, Inc., Chicago, Ill.

*Electric Supply Corp., Chicago, Ill.

guide in the discussion of office lighting in my capacity with an electrical distributor.

We of course should all be aware that the tables compiled by the authors do not allow us to put our finger on any one fixture and say that there is the answer to our problem. But certainly it gives us an intelligent start in the analysis of the individual cases in question in our dealings with the user.

In the compiling of data for such a paper much subjective reasoning has to be used — reasoning which will vary from engineer to engineer. For example, I question some of the maintenance factors the authors have used. However, these are things that should be taken into consideration when the specific application is being discussed and the authors certainly should not be criticized for their opinions.

It is regretted that instead of using the A, B, C, D glare factor ratings which Mr. Taylor used in his office lighting paper, the authors were forced to rate glare factors in absolute numbers. Absolute numbers in the glare ratings have little meaning and can be misleading. Therefore, it is extremely desirable to talk about ranges of glare factors such as was done in the office lighting paper.

In conclusion, I would like to pose one final question. Our whole basis of the quality movement in industrial lighting resulted from the realization that the tasks performed in an industrial area were equally as critical as those performed in office areas. Why then are glare ratings up to about 15 to 20 considered comfortable in an office, while glare ratings of 50 to 75 are considered adequate for *industrial* areas?

WOLFE NOTTELMAN*: "Comfort in lighting," either industrial or commercial, has the same problems in Canada as those prevalent in the United States.

"Quality" is the keynote which must be expounded nationally and internationally if the lighting industry — by this is meant the manufacturer of "quality" and "efficient" equipment — is to be recognized by the consumer as a very important factor, as well as a very influential one in helping to determine the welfare and employer-employee relationship of our present industrial and commercial systems.

As was pointed out in the paper, "quality of illumination in industrial areas has been expounded by leading illuminating engineers on many previous occasions." Undoubtedly much more time will pass before "quality in lighting" will be generally accepted throughout the industry. However, it is the duty of every person connected with the lighting industry to advocate and preach "quality" until every industrialist and every owner or operator of a commercial establishment becomes fully aware of what quality lighting means to him personally. Of course, we must first clean house in our own industry by producing only "quality" and "efficient" equipment.

As lighting equipment improved in efficiency the unit cost decreased. As the level of illumination increased, the task was made easier; however, only up to a point. It became evident that factors hindering further improvements in seeing conditions appeared. The point was reached where further addition of light alone hindered rather than helped, and thus caused sufficient discomfort to bring about a reduction in seeing ability. Light quantity cannot be the only criterion considered in a quality installation. Items such as ceiling and wall finishes, brightness, ratios, conspicuous and annoying sources of brightness and glare, must all be kept to a minimum; thus, the complete visual field must be considered and not only that area immediately surrounding the task.

*Amalgamated Electric Corp., Ltd., Toronto, Ont.

As was pointed out in the paper, "the first cost and annual operating cost per square foot would vary depending on whether the area was larger or smaller than that used as an illustration." There is no quarrel with the aforementioned statement; however, an illustration seems to be lacking indicating how these costs were derived. It has always been felt that only too frequently a potential fluorescent customer has been lost because of the high initial cost. With all due respect to the authors of this paper, an endeavor is here made to present a suggested method of determining the cost to own and operate a lighting system. Canadian figures, especially those found prevalent in Ontario, will be used for actual costs. Where estimates have been made, they are believed to be sound and reasonable. These systems are illustrated so that a simple comparison might be made between these systems when installed in the United States or Canada. Equal burning hours have been used.

In choosing as examples installations #4 of Group I, #12 of Group II and #19 of Group III, no particular reason can be given, each type having been selected at random. By simple calculation, according to the Bradley-Taylor paper, the annual costs to own and operate the above illustrations are:—

#4 — $2,428.55; #12 — $2,214.95; #19 — $2,696.25

To illustrate a breakdown as might be used in Canada, the accompanying Table D-1 is submitted. If we assume that the lamps have an economical life of 7000 hours, all the lamps would be replaced every 1.75 years under normal operation of 4000 hours per year.

In this discussion no attempt is made to verify or discount the quantity of luminaires required for a 50-foot-candle installation. Total quantities for this illustration have been used as indicated in the paper.

A great deal of credit is due the authors for their attempt to satisfactorily present a paper which is so highly controversial; it is hoped that more illuminating engineers will now come forward to present their views on this subject.

TABLE D-1.

No.	Item	#4 Group I	#12 Group II	#19 Group III
1.	Nos. of luminaire	84	78	172
2.	Lamps per luminaire	4 - 40	4 - 40	2 - 40
3.	Watts per luminaire	192	192	96
4.	Total watts (1 × 3)	16,128	14,976	16,512
5.	Burning hours per year	4,000	4,000	4,000
6.	Energy cost per year at 1c kwh.	645.12	599.04	660.48
7.	Lamp life, hours	7,000	7,000	7,000
8.	Nos. of lamps replaced annually	192	178	196
9.	Net cost of lamps each (1.8)	1.35	1.35	1.35
10.	Labor cost of lamp replacement, each	.25	.25	.25
11.	Net cost per lamp replaced (9 plus 10)	1.60	1.60	1.60
12.	Annual total cost for lamp replacement (8 × 11)	307.20	284.80	313.60
13.	Estimated cleaning cost per luminaire	1.00	1.00	.50
14.	Annual cleaning cost, 1 per year (1 × 13)	84.00	78.00	86.00
15.	Cost of luminaires, each trade net, with lamps	51.40	51.40	30.45
16.	Total initial cost of luminaire (1 × 15)	4,317.60	4,009.20	5,237.40
17.	Wiring and installation estimated at $10.00 per luminaire ($10 × #1)	840.00	780.00	1,720.00
18.	Total initial installation cost (16 plus 17)	5,157.60	4,789.20	6,957.40
19.	Amortization cost, 13% per year to cover interest on investment, insurance, etc. (13% of 18)	670.49	622.60	904.46
20.	Total annual owning and operating cost (6 & 12 & 14 & 19)	1,706.81	1,584.44	1,964.54

G. J. TAYLOR and R. D. BRADLEY*: Mr. Caverly emphasized a very important point in stating that upward light alone will not accomplish what we seek for comfort of seeing. The fact is that "danger" lies ahead if we only think of upward lighting as a solution to quality illumination. So a note of "warning" is in order. For ultimate comfort it is imperative that we follow the I.E.S. recommended practice of reflectances. Let there be no misunderstanding about the proper balance of brightness ratios for seeing comfort. Unless these ratios are proper, discomfort may result by adding too much uplight. For instance, if the immediate surrounds about the seeing task are dark and the ceiling bright (by comparison) discomfort is sure to result particularly where difficult and critical seeing tasks are encountered over long periods of time. Neither should floors be so light as to be bright with respect to the immediate surrounds of the seeing task. The immediate surrounds which implies, machinery, bench tops, background inspection surfaces, etc. must have light finishes when high components of upward light are used. With this in mind, and for other reasons, there are many industrial areas which will benefit in comfort and cost in using Group II luminaires with moderate uplight rather than Group III luminaires with higher percentages of uplight.

Mr. Caverly suggests the use of Troffers for industrial areas. The authors are in full accord with his expressed reasoning. He refers to office areas where comfortable lighting may be achieved with all downlight using Troffers. This is covered by Taylor in a paper on "Appraisal of Modern Fluorescent Office Lighting Systems," (ILLUMINATING ENGINEERING, March 1951). Ideal lighting for comfort is approached, as is shown, with Troffer designs of parabolic aluminum or low brightness lens plates. Where room conditions permit and production benefits in overall comfort of workers, then by all means let us recommend and use acoustically treated ceilings with air conditioning and Troffers in "industrial" areas.

Mr. Macy proposes many interesting angles in favor of quality illumination. One might say that the four factors in his opening paragraph for considering good lighting are old stuff. But wouldn't it be perfectly delightful if the "specifier" of lighting equipment truly appreciated the value of these factors and the "user" were made to understand the real significance of them. As authors we realize that cost data cannot be expected to apply accurately all over the country or, as a matter of fact, all over any state of the country. However, the costs presented do direct attention to comparative economics. If a buyer of industrial lighting equipment should decide between two systems because of a choice of comfort through glare factor rating (which Mr. Macy likes) he can compute costs relating to his own conditions to determine his final choice of the lighting system for economical reasons. The point is, however, that he would narrow his acceptance to glare factor ratings within a close proximity of each other rather than look at the cost angle only.

Mr. Macy's reasons for greater acceptance today of lighter finishes throughout a room are most interesting. We agree with him that when upward components of light are used, ceilings must not be allowed to deteriorate materially. Our discussions with industrialists on this factor alone prompted us to word our "conclusion" as we did. We also agree wholeheartedly with the six points on maintenance. Luminaires should be heavy-duty constructed with durability in mind the same as the machinery in a factory area. Finishes should also be considered to match factory atmospheric conditions and that is why we stress the use of porcelain enamel. He wants ease of maintenance. Why not? It can be accomplished as it has been before, bearing in mind that quick detachable reflectors which can be washed on the floor will save time and money and accidents.

Mr. Barr's remarks about maintenance are pertinent and definitely important. Why is it that factory executives concern themselves about the proper amount of light to use and then allow it to dwindle to surprisingly low levels? Depreciated light is very costly in ever so many ways, especially in connection with Mr. Barr's concluding sentence.

The comments and results of Mr. Sell's discussion are not only a valuable contribution to the proceeds of this paper but to the lighting industry as well. If Mr. Sell's test data are used for the porcelain enamel reflectors some interesting interpretations can be made. About one third of the light from lamps is directed *directly* downward in the non ventilated unit. About two thirds is *reflected* downward. Considering the unit efficiency of System #2 at 78.5 per cent the useful lumens become 7220, of which 2410 are cast directly downward and 3800 reflected downward considering the 21 per cent depreciation of the reflecting surface. The total light output after ten months, not counting lamp depreciation becomes 6210 lumens. If throughout useful life of the lamp it is considered that the lamp and dirt accumulated on the lamp depreciates an average of 25 per cent the maintenance factor based on the 21 per cent reflector depreciation becomes: MF = .64. Using the same reasoning for the porcelain enamel reflector having 8 per cent uplight, MF = .71. With wider top reflector openings the maintenance factor appears to improve as indicated by Mr. Sell's tests. In any event, the maintenance factors used in the paper appear to be correctly applied. Tests of the nature conducted by Mr. Sell are very badly needed by our industry. They should be conducted on a much larger scale so that some of the guessing in applying maintenance factors to lighting installations can be eliminated.

No one in the lighting industry has given more time, attention or thought to quality of illumination in industrial areas than Mr. Linsday. Consequently, his supporting comments in behalf of our paper give us a sense of satisfaction in the work we have done. He has given further evidence of the value of ventilated reflectors and indicates additional tests on the subject are underway. May we urge that his results be published as soon as data become available? Our experience with the use and application of glare factors convinces us they are easily understood by all who will listen to the story in connection with them. They help in getting better lighting jobs installed. We acknowledge and accept the precaution noted by Mr. Linsday concerning the 50 75 range of glare factors. If we could wean people away from System #4 with a glare factor of almost 150 to System #14 with about 50 suddenly and completely we would be accomplishing a miracle. Yes, there are many production areas where glare factors of 15 are in order. We like the idea of rounding off glare factor numbers as suggested.

Mr. Linsday refers to Systems #14 and #17 as a standoff in costs. We want to emphasize that these costs are based upon room finishes comparable to office areas—ceiling 75 per cent and wall 50 per cent. With room finishes of 50/30, System #17 becomes about 20 per cent higher in cost when comparing similar type lamps. Our paper as stated shows a gap in amount of upward light in the range of 15 to 30 per cent. It is difficult to ascertain how these ranges should be sliced. Perhaps the old rule of "doubling" footcandle values to appreciate significant improvement in seeing would

*Authors.

be worthy of consideration. Accepting System #14 as a good one we start with 12 per cent uplight; then 25 and next 50 per cent. One thing certain is that for best comfort of seeing and lowest glare factors, shielding is desirable in both directions for the 25 per cent and 50 per cent uplight systems.

Mr. Zahour refers to our progress with incandescent luminaires in the past where shielding and upward lighting was advocated in behalf of quality illumination. Even Glassteel Diffusers were substantially brighter (footlamberts) than present day 2 40-watt RLM fluorescent units. Yes, the lighting industry continues to enjoy progress in fulfillment of its duty toward mankind. As Mr. Zahour states there is a growing tendency toward higher reflectances for wall and ceiling finishes in factories but we are still confronted with the lower reflectances and where they prevail we must give them due consideration in our ultimate recommendation of a lighting installation. Mr. Zahour points to the application of luminaires for high bay lighting and refers to the R 57 type reflector lamps. High bays should be considered from a comfort of seeing standpoint too. Ceilings should be light in color and some light cast onto them. Luminaires are available to do this although there is room for improvement in this field. These remarks would leave the R 57 out of the picture as far as comfort is concerned. Perhaps, but there are many areas such as: foundries, forge shops, steel mills and the like where these lamps have a very definite application. One cannot argue comfort all the way down the line where maintenance economics may be of great importance in such areas as just mentioned. So the R 57 is another tool in our lighting kit and should not be overlooked.

Although Mr. Wakefield's comments are brief he has asked and said much in a few words. He has made and is making some mighty fine contributions concerning visibility. His latest paper on "Control and Measure of Directional Flux at the Task" (ILLUMINATING ENGINEERING, March 1952) shows photographically some interesting material on visibility with relation to location of light sources. And so his opening questions on quality illumination into which he resolves quality of job classifications is food for thought. However, we cannot wait for specific studies of this nature and must apply our present knowledge of quality illumination and seeing comfort to the best of our ability. It is recognized that reflected glare is absent in our studies, which prompted Mr. Wakefield's last question. Visibility at the task must be added sometime in the future. To some extent we already have devices to measure visibility at a task such as the Luckiesh Moss Visibility Meter. The proper use of this instrument quickly determines the necessary brightness of the task for easy seeing. Even though it is possible to achieve the brightnesses required it is not always possible to do so in a practical way nor to do so with the emphasis of present day thinking on economics.

As an engineering profession we can be proud of our advances in lighting both in applied illumination and economics. We have industry accepting, in general, our recommended lighting levels and are not doing too bad a job with surface reflectances throughout a room. We are now asking that more attention be given to quality illumination from overhead general lighting equipment. It would perhaps be wishful thinking to say that our *last* step would be maximum visibility of the task. At least, it might be said it is our next step. The question with regard to maintenance in favor of open top reflectors is answered by another discussor. We do wish to agree with Mr. Wakefield that maintenance should not dictate to visibility. But, we are of the opinion that where visibility remains the same maintenance costs will dictate the type of equipment that will be used, not to mention the decision when the lower cost system improves visibility.

When we wrote our paper we kept in mind the technical aspects of the subject and attempted to write it in a practical way so that specifiers and application engineers might understand and recommend quality lighting systems for production areas. Mr. Johnson does not agree with this thinking and, of course, he is entitled to his own opinion. On the other hand, we have been approached by many members of the Society who expressed the feeling that the paper was too technically written. They claim this particular paper could have been written for the greater majority of our membership who have been seeking information written from a practical point of view. We also felt our title was short, which is usually desirable, and descriptive and no attempt was made in the paper to mislead anyone about the specific problems treated. The economic factors mentioned by Mr. Johnson were not omitted but they do represent a very small percentage of the overall operating costs. We attempted to show the importance of room finishes by including four such finishes in Table I. We also stress the importance of maintaining these finishes in our "Conclusion," especially with Group III Systems. We fail to see how our paper implies that luminaires are cleaned the same number of times per year. Actually, the cleaning varied from a frequency of 6.6 months to 12 months.

It is true that glare factors do not consider reflected glare, although we do agree that reflected glare in many industrial applications should be considered. There was no intent, nor do we think the paper is so written, toward regimentation of the lighting applications in the minds of the readers. We have, as a matter of fact, described the flexibility of application of lighting systems. It would be a worthy event if we could channelize the minds of industrial users of lighting toward Group II and III Systems and away from the Group I Systems.

We do not discount the value of mercury lighting or other types of lighting for high bays, but this paper was restricted to the use of fluorescent lamps and not for "high bay" applications in that sense of the world. Consideration was only given to luminaires that were commonly used in industrial applications. As a matter of fact, there are more than 19 types even though Mr. Johnson cannot conceive the necessity of appraising that many systems. While he believes that the school field is restricted in luminaire types we question the validity of this statment. Giving credit to the better judgment of those recommending luminaires, which would not include RLM, it is amazing the many different types specified for classrooms. To mention only a few types in use: metal sided units in baked enamel and aluminum, luminous sides in glass and plastic, illuminated metal sides, all these with different sloping sides including vertical side panels and all with varying shielding angles. Then there are many types of Troffers with louvers, glass lenses and parabolic aluminum. Bear in mind that the above mentioned units may employ the use of 1, 2, 3 and 4 lamps in standard fluorescent slimline and the 40 watt T 17 fluorescent lamp. Add to this long list the luminous indirect, louverall, luminous ceiling and the grid type systems. Indeed classroom lighting also has its problems of many types of luminaires, which should be appraised in terms of economics and comfort. May we say that the same applies for all applications where seeing is important to working men and women.

We are pleased to know that Mr. Osborn as a successful electrical contractor finds our paper valuable to the electrical contracting profession. We endeavored to write our

paper in a practical way, although by necessity had to slant it toward technical terms to keep it factual.

While it is not the purpose of our paper to discuss relative merits of one type of distribution system over another it is interesting to note that substantial savings may be obtained by using a combined light and power system utilizing a 480Y/277 volt grounded neutral system for both lighting and power. Fluorescent lamp ballasts are available and have been used successfully for operation on 277 volts. In addition to economy in the use of such distribution systems there is a considerable saving in copper and iron. Being faced with material shortages during the Defense Program such savings are vastly important today. Mr. D. L. Beeman of the General Electric Company prepared an interesting table of comparisons of three types of distribution systems in this connection and it is reproduced below showing cost data.

Type of System	Approximate Initial Cost per kva
(a) Separate Lighting and Power Substations. 208Y/120 volt, 3 phase, 4 wire for lighting; 480 volt, 3 phase power for motors, etc.	$82.00
(b) Combined Lighting and Power Substations. Substation supplies power directly at 480- and 120 volt lighting through step down dry type transformers.	$59.40
(c) Combined Lighting and Power Substations. 480Y/277 volt, 3 phase, 4 wire system supplies power at 480 volts and lighting from phase to neutral at 277 volts.	$46.70

Mr. Gilleard's remarks concerning glare factor ratings are appreciated. It is true that we selected one room condition in our paper and for the very reasons suggested by Mr. Gillard. The typical "glare factor" table presented with his discussion indicates the simplicity with which such ratings can be selected for varying conditions.

Mr. Gilleard disagrees with the three Groups of luminaires suggested in the section under "Application of Luminaires." As we understand it, he would recommend only the top quality luminaires (Group III) for all classified seeing tasks from 30 footcandles and over. Theoretically he may be right in his viewpoints. However, in carefully reviewing the *I.E.S. Lighting Handbook*, "Levels of Illumination" for interior lighting, we do not find general adherence to statements made by Mr. Gilleard with regard to specular reflections in the 30 footcandle classification. Where a multiplicity of specular reflections would prevail in a given shop in the 30 footcandle level we too would recommend the Group III luminaires, although this would be an exception to the rule. Moreover, it would be a daring statement for anyone to say that 2-40 watt (System #4) RLM luminaires with no uplights are completely out of order in their present day application. Yet, a conservative estimate would reveal that 75 per cent of fluorescent lighted factories use these units for all footcandle levels. To be sure the glare factor rating is of the order of 140 and out of the realm of acceptability for good seeing comfort. Yet the addition of 10 per cent uplight (System #12) in the same type luminaire drops the rating below 100 and at less initial cost. System #19 with 30 per cent uplight does show a glare factor materially under 50 but at initial costs of over 30 per cent higher.

We realize that if a given seeing task requires 50 footcandles and it is arbitrarily cut down to 35 footcandles (50 less 30 per cent) then System #19 at 35 footcandles would cost about the same as System #12 at 50 footcandles. We do not believe in adjustments of this nature for economic reasons and feel that established levels for specific seeing tasks recommended by I.E.S. should be religiously followed.

Mr. Marks prefers an A, B, C, D method of glare rating in ranges rather than absolute numbers. We published numbers only to show the wide variation of comfort rating in industrial units commonly used. Our ultimate hope is that users of industrial lighting will be moved to install the more comfortable systems carrying the lower numerical glare factor numbers. The question as to why recommend glare ratings of 15 to 20 for comfort in offices and 50 to 75 in factories is a good one. We referred to work by Harrison Meaker in this connection. We are also of the opinion that office workers "glue" their eyes to the job for long periods of time. Industrial factory operators, in general have "roving" eye work with less prolonged concentration. Furthermore, some leniency was given to industrial glare factors in reasoning that the widely used 2-40 watt RLM luminaire had set up a form of standard in industry. It must be borne in mind that there are many seeing tasks in industry that are much more critical than in offices. Where this is true, Group III luminaires are to be recommended and there may be times when luminous indirect lighting or luminous ceilings would be desirable with resultant glare factors below 20.

It is always a genuine pleasure to exchange views on lighting matters with our neighboring country — Canada. We appreciate Mr. Nottelman's appreciation of the importance of quality lighting in industry — nationally and internationally. The statement that as levels of illumination are increased seeing becomes easier only up to a point may be true in some instances but not true in many other instances. Space does not permit discussing this point. For the benefit of those inexperienced in the value of quantity of illumination, the authors wish to state that, in general, as levels increase, seeing improves even up to thousands of footcandles. Naturally, brightness engineering must be duly considered.

We would have been pleased to publish our calculated data on costs and glare factors. However, we computed over 3,000 figures and the limitation set on our paper allowed only for condensation of these data as presented in Table I. Mr. Nottelman presents a table of costs applying to Toronto. This is typical of the method we employed except our computations were much more involved in arriving at costs. As stated in the paper, costs were based on competitive bidding through union electrical contractor, purchasing materials and equipment through an authorized electrical contractor who was responsible for the installation of thousands of industrial type luminaires. For example, System #4 was based on three 8 foot sections per circuit. Panelboard, pipe and wire costs per circuit were computed. AF wire per luminaire was included and man hours installation added. This was all broken down to an installed cost of $14.25 per 8 foot section for System #4. Due to the design and construction of luminaires in System #19 the cost per 4 foot section came out to be $11.28 per unit. This typical example indicates the wide range in installed costs of luminaires. Obviously, costs will vary from one city to another in Canada and the United States. Amick and Barr in their paper on "Fundamentals of Lighting Cost Analysis" (ILLUMINATING ENGINEERING, May 1952), presented a suggested means of computing costs on some standardized basis. The idea is a good one but wiring costs must be added if true costs are to be known.

Our costs in Table I are relative and to that extent worthwhile. In this connection we feel that System #4 (2-40 watt) which was the most widely used luminaire in industry must give way to System #12. Why would anyone want to pay 78c a square foot for #4 with its glare factor well above 100 which means discomfort when #12 can be had at

73c a square foot with a glare factor below 100 and some degree of comfort? But some day we will give due consideration to comfort of seeing and pay a little more to get glare factors below 50 as in System #14 at 86c per square foot. Moreover, where high comfort is required with low glare factors the Group III luminaires approaching a dollar a square foot will prove to be economical purchases. Since we calculated all charges for operation, maintenance and amortization in our annual operating costs we cannot agree with those shown by Mr. Nottelman. We are somewhat surprised to see how closely our published annual operating costs agree with those calculated in item 20 by Mr. Nottelman.

The authors wish to take this opportunity to thank all of the discussors who presented their views in connection with our paper. The large number of discussors would indicate the importance of the subject of comfort and costs in the application of industrial type equipment. It is evident that there is a need for continued study in the application of industrial luminaires to approach proper lighting solutions. This approach must be arrived at through scientific studies and practical considerations.

Unusual Ceiling Technique in Clothing Store

The ceiling height of this sales area at the Gately Clothing Co., Duluth, varies from 11 feet at the front to 14 feet at the rear of the store. At each of the four "steps" there is a lateral cove containing two 72-inch T-8 slimline lamps on channel, to reduce contrast on the adjoining area. In the main ceiling are ten recessed luminaires with glass lenses, each unit having three 96-inch T-12 cool white lamps. These units are flanked by eighteen 300-watt incandescent downlights. Cornice and wall cases contain twenty-one 96-inch T-12 lamps on channel. Illumination in the sales area was 65 footcandles after 30 days' operation.

In the ceiling of the mezzanine at the rear of the store are three 96-inch recessed units, and in the office under the mezzanine a level of 125 footcandles at desk level is provided by twenty-one troffers, each with two 40-watt de luxe cool white lamps.

Floor area is 16 x 76 feet; ceiling is flat white acoustic tile; walls are pale green. All woodwork is blonde and the floor is of light gray tile. Installation designed and installed by W. E. Ellingsen, Architect, Duluth; and Morris G. Braden, Illuminating Engineer, Minnesota Power and Light Co., Duluth.

Looking toward front of store.

Looking toward rear of store.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Artificial Moonlight Demonstrated To Scientists and the Military

A number of scientists and military men were invited by Dr. L. M. N. Bach, Director of the Artificial Moonlight Project, to attend a demonstration at the Bonnet Carre Spillway, Louisiana, on February 6. The demonstration of artificial moonlight, Project #2 of the Coordinating Committee for Defense, was preceded by a briefing, consisting of the following:

1. Introduction and Outline of Problem — L. M. N. Bach, Director of Artificial Moonlight Project, and Department of Physiology, School of Medicine, Tulane University.
2. Photometric Procedures — C. J. Sperry, Jr., Department of Electrical Engineering, College of Engineering, Tulane University.
3. Psychophysical Procedures — R. I. Long, Department of Psychology, College of Arts and Sciences, Tulane University.
4. Demonstration of Photometric Calibration C. J. Sperry, Jr.

The observations of the two Co-Chairmen of the Coordinating Committee for Defense, Major G. D. Mills and A. F. Wakefield, indicated (a) that the method is peculiarly effective, and (b) it is well supported by the Military as Dr. Bach is now under contract and not proceeding under a voluntary basis, as originally commenced by this Committee.

Milwaukee Section Stocks Local Libraries

The board of directors of the Milwaukee Section of the I.E.S. has decided to donate a copy of the *I.E.S. Lighting Handbook* to the Milwaukee Public Library and to the libraries of Wisconsin State College and other universities in the area. This decision was made after a survey of information on lighting available, of which much was fifteen to twenty years old and very little on fluorescent lighting.

In addition to the *Handbook*, the Public Library is receiving, courtesy of the Milwaukee Section, copies of all the I.E.S. Recommended Practices, Data Sheets of the latest series and Technical Committee Reports.

Four New Fellows Elected

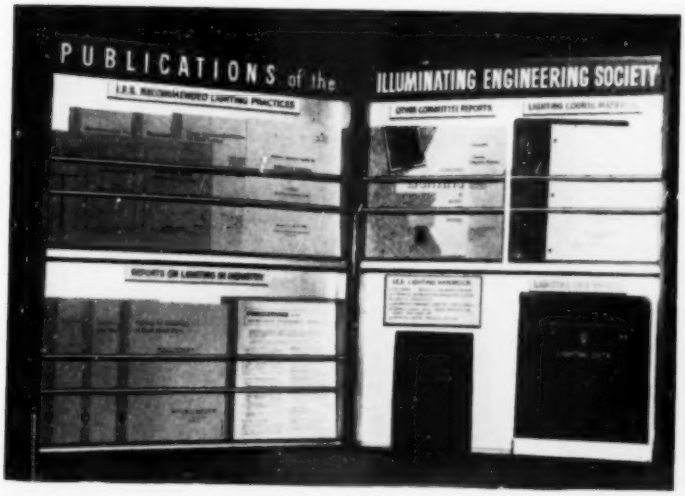
Four distinguished Members of I.E.S. were elected to the Society's highest grade of Fellow, by letter ballot reported to the Council Executive Committee, March 12. The elections, on recommendation of the Board of Fellows, were for:

J. W. Bateman, Toronto Section, Manager of the Lighting Service Department of the Canadian General Electric Co., Ltd.

Dean Farnsworth, Lieutenant Commander, U. S. Navy, Medical Research Laboratory, Head of Visual Engineering Department, New London, Conn.

Eric B. Hallman, Illuminating Engineer with Electric Service Manufacturing Co., Philadelphia, Pa., authority in field of outdoor floodlighting and transportation.

William P. Lowell, Jr., Manager of Commercial Engineering, Sylvania Electric Products, Inc., Salem, Mass.



PUBLICATIONS Office has designed a new portable display case for I.E.S. publications, shown above open for use, and being carried. Ten cases are being built, one for each Region, to be used in turn by Sections and Chapters within the Region. The display, including the publications themselves, weighs less than 25 pounds and measures only 30x24 inches when closed, making it readily portable. Opened on a table, it measures 40 inches wide by 30 inches high. The display is painted royal blue and gold. The Regional Vice-President for each Region will act as custodian of the display and will schedule its use within his area. Extension of the program to include a similar display case for all Sections and Chapters will depend largely upon the good use of these first models.

Here and There with I.E.S. Members

Part of the exhibits and a few of the 105 people in attendance at the Industrial Vision Conference held at Wilkes College, January 30, in Wilkes Barre, Pa. The Conference, sponsored by the College with the Eastern Pennsylvania Section, I.E.S. and the Northeastern Pennsylvania Optometric Society, was to show small industries how best to utilize light, color and vision to aid employees in their jobs.

Lloyd M. Johnson (center), commissioner of streets and electricity for the city of Chicago, receives a citation from the Chicago Lighting Institute in recognition of the improved street lighting program, now one-third completed. Institute president, G. K. Hardacre, makes the presentation as Mayor Kennelly looks on. This is the first award ever made by the Institute.

The February 23 meeting of the Quebec Chapter was in cooperation with the interior decorators of the city, with the theme, "Comparison between Good and Poor Residential Lighting." Attendance was 280.

Members of the St. Louis Section during the Cocktail Hour preceding their February 19 dinner meeting.

Regional Conference Talk Wins National Award

The featured talk during the luncheon program of last year's Great Lakes Regional Conference has just won a national award. This should hardly surprise the several hundred I.E.S. members who heard George A. Bowie of Firestone Tire and Rubber Co. address the Regional group, with his speech, "Going Somewhere." The talk was wire recorded, later re-broadcast over WGAR, and by coincidence heard by someone from the Freedoms Foundation at Valley Forge. Subsequently, the I.E.S.-sponsored talk was awarded a national award by the Foundation.

Hamilton Ontario Chapter Sponsors Lighting Fundamentals Course

A course on Lighting Fundamentals was included in the curricula of McMaster University under the sponsorship of the Hamilton Ontario Chapter, I.E.S. The series of eight lectures were given, Thursday evenings, from October 23 to December 11. Speakers were supplied by the Chapter and Course Director G. M. Whittaker was in attendance. Topics covered were:

Light and Sight, by John Harrison, Holophane Co., Ltd.
Fundamentals of Illumination, by Grant F. Davidson, Hydro-Electric Power Commission.
Light Sources—I, by G. F. Mudgett, Canadian Westinghouse Co.
Light Sources—II, by H. C. Jones, Canadian General Electric Co., Ltd.
Illumination Design, by D. F. Davis, Northern Electric Co., Ltd.
Industrial Applications, by W. A. Dalrymple, Amalgamated Electric Co., Ltd.
Office and School Applications, by Frank Reed, John C. Virden Co., Ltd.
Store and Display Applications, by R. C. Allison, The T. Eaton Co., Ltd.

The average attendance was approximately 35 and the Chapter has been asked by McMaster University to sponsor a similar course during the coming year.

These Sections Had a Good Idea

Three or four "good ideas," unusual or especially successful local projects, undertaken by I.E.S. Sections or Chapters will be outlined here each month.—Ed.

1. **Cleveland Section** publicity chairman (H. J. McCullough) has had some interesting assignments in the matter of putting I.E.S. on the air. His mission was to approach Cleveland radio and video stations and show them that I.E.S. sponsored programs are of general interest to the public, from the angles of sight, safety, health and better living. Two such programs were made during last year's Great Lakes Regional, and the recent "See and Live" street lighting meeting (March I.E., page

LIGHTING CALENDAR

Society Events

April 30 - May 1, 1953 — Midwestern Regional Conference, Hotel Radisson, Minneapolis, Minn.

May 14-15, 1953 — East Central Regional Conference, Hotel Lord Baltimore, Baltimore, Md.

May 18-19, 1953 — Southern Regional Conference, Sedgefield Inn., Greensboro, N. C.

May 25-26, 1953 — Great Lakes Regional Conference, Syracuse Hotel, Syracuse, N. Y.

September 14-17, 1953 — Illuminating Engineering Society, National Technical Conference, Commodore Hotel, New York, N. Y.

Industry Events

April 27 - May 1, 1953 — Society of Motion Picture and Television Engineers, Hotel Statler, Los Angeles, Calif. Semi-Annual Convention.

April 13-14, 1953 — Annual Convention of the Electrical Contractors Association of Ontario, Royal Connaugh Hotel, Hamilton, Ont.

April 28-30, 1953 — The American Society of Mechanical Engineers (Spring Meeting), Deshler-Wallick Hotel, Columbus, Ohio.

May 7-8, 1953 — Public Utilities Advertising Association, Annual Convention, Hotel Chase, St. Louis, Mo.

May 18-22, 1953 — National Materials Handling Exposition, Convention Hall, Philadelphia, Pa.

May 19-22, 1953 — Electrical Manufacturers Representatives Association of Michigan, Exhibition Building, Michigan State Fair Grounds Detroit, Mich.

May 24-28, 1953 — National Association of Electrical Distributors, 45th Annual Convention, Conrad Hilton Hotel, Chicago, Ill.

June 1-4, 1953 — Edison Electric Institute, 21st Annual Convention, Atlantic City, N. J.

June 9-12, 1953 — Store Modernization Institute, Fourth Annual Modernization Show, Madison Square Garden, New York, N. Y.

June 15-19, 1953 — American Institute of Electrical Engineers, Summer General Meeting, Atlantic City, N. J.

June 22-26, 1952 — Annual Convention of the American Society for Education, University of Florida, Gainesville, Fla.

June 28 - July 2, 1953 — American Society of Mechanical Engineers, Semi-Annual Meeting, Statler Hotel, Los Angeles, Calif.

July 5-10, 1953 — New York Lamp Show, Hotel New Yorker, New York, N. Y.

August 18-21, 1953 — American Institute of Electrical Engineers, Pacific General Meeting, Vancouver, B. C.

September 21-26, 1953 — International Association of Electrical Inspectors, 25th Jubilee Meeting, Edgewater Beach Hotel, Chicago, Ill.

September 23-25, 1953 — Canadian Electrical Manufacturers Association, Annual Meeting, General Brock Hotel, Niagara Falls, Ont.

October 5-9, 1953 — Society of Motion Picture and Television Engineers, Semi-Annual Convention, Hotel Statler, New York, N. Y.

October 19-21, 1953 — American Standards Association, 35th Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

October 19-23, 1953 — National Safety Council, 41st National Safety Congress & Exposition, Chicago, Ill.

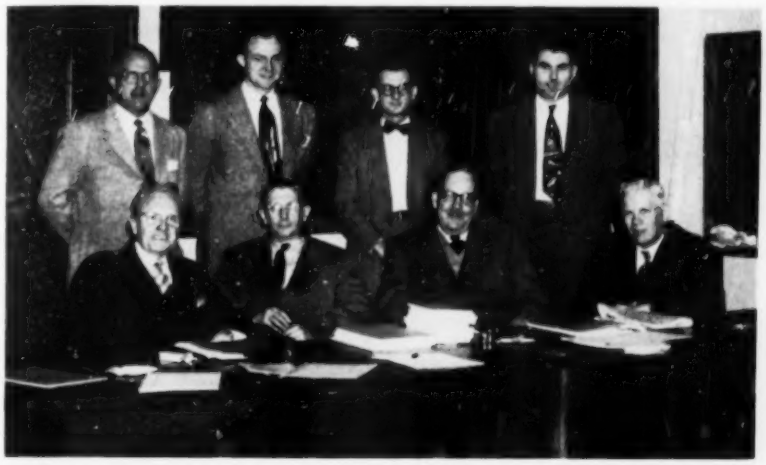
November 9-12, 1953 — National Electrical Manufacturers Association, Haddon Hall Hotel, Atlantic City, N. J.

November 17-19, 1953 — National Electrical Contractors Association, Miami Beach, Fla.

November 29 - December 4, 1953 — The American Society of Mechanical Engineers, Annual Meeting, Statler Hotel, New York, N. Y.

January 18-22, 1954 — American Institute of Electrical Engineers, Winter General Meeting, New York, N. Y.

March 8-11, 1954 — National Electrical Manufacturers Association, Edgewater Beach Hotel, Chicago, Ill.



MEETING of the Southern group of the Committee on Lighting in the Textile Industry was held in Charlotte, N. C., February 13, to discuss plans for further study of this industry in the southern area. Present at the meeting were: seated, Roy A. Palmer, Arthur A. Brainerd, Hamilton Corey, Glenn E. Park; standing, D. Mack Woodside, Martin L. Harkey, Jr., J. H. Welch, Jr., Benjamin C. Swaim.

SCHOOL Lighting Clinic at Chicago Lighting Institute March 6 attracted 192 school administrators and engineers. Some 18 speakers were featured at the all-day sessions. Sponsors were the Institute and the Chicago Section of I.E.S.

10A). Round table discussions featuring speakers from the latter symposium were on Cleveland stations, as well as broadcast interviews with I.E.S. program speakers. Two-way benefits — further dissemination, and public exposure to I.E.S.

2. **Milwaukee Section** drew a big crowd with an appeal to the urge for lighting education, coupled with the nostalgic appeal of an old-fashioned community supper. After supper (*not* dinner) at one buck apiece, the group heard Tom Dustin (A. C. Electric) and Howard Grosh (Westinghouse) outline highlights from the *I.E.S. Lighting Handbook*.

3. **Chicago Section** cuts down the time taken at meetings for miscellaneous announcements by mimeographing these on a sheet handed out to all attendees. Members read them at their leisure. Gets more attention that way, too.

4 **Carolinas Section** is another, of several, Sections which publishes its own local I.E.S. "newspaper." Mimeographed, to all members.

Scholarships Established for Illinois Illumination Students

Six scholarships for students in the Illumination Option at the University have been established by the Holophane Company, to begin with the fall semester in 1953. Assigned on a semester basis, at $200 each, two scholarships are awarded to juniors in the second semester; two to seniors in the first semester and two to second semester seniors. The awards are made by the committee on special undergraduate scholarships on the recommendation of the teaching staff in Illuminating Engineering.

School Lighting Clinic Educates Educators

Leading experts in school lighting had an opportunity, March 6, to educate the educators in the many aspects of school visual environment.

Under the joint sponsorship of the Chicago Section, I.E.S., and the Chicago Lighting Institute, some 200 school administrators, architects and engineers attended an all-day clinic on the subject, at the Institute. Eighteen speakers participated in the especially successful meeting.

Included in the subjects covered were:

Morning Session — Chairman: Dr. Darrell R. Blodgett, Education Director, Public Schools, Wheaton, Ill.

Lighting the Way — Color Film, produced by the F. W. Wakefield Brass Co., Vermilion, Ohio.

Availability of Daylight During School Hours —Clint Youle, "The Weather Man," Station WNBQ, Chicago, Ill.

Measure Your Lighting — R. J. Diefenthaler, General Electric Co., Chicago, Ill.

School Work Made Easier — C. J. Allen, General Electric Co., Cleveland, Ohio.

Economics of Wiring — M. J. Feron, Samuel R. Lewis & Associates, Chicago, Ill., and L. C. Haskell, Public Service Co. of Northern Illinois.

Question Forum — Paul Fisher, Public Service Co. of Northern Illinois, Chairman of the Conference.

Afternoon Session — Chairman: Rev. Stanley C. Stoga, Assistant Superintendent, Archdiocese of Chicago School Board.

Light Sources for Schools — Carl F. Jensen, Westinghouse Electric Corp., Lamp Division, Chicago, Ill.

Lighting the Classroom — George Gilleard, Curtis Lighting, Inc., Chicago, Ill.

Lighting Vocational Areas — R. D. Bradley, Day-Brite Lighting, Inc., St. Louis, Mo.

Lighting Play Areas—Benjamin Electric Mfg. Co., Des Plaines, Ill.

Lighting for School Dramatics — Theodore Fuchs, Professor of Dramatic Productions, Northwestern University, and Consultant, Hub Electric Co., Chicago, Ill.

Lighting Maintenance — R. R. Wylie, Sylvania Electric Products, Inc., Salem, Mass.

Question Forum—Paul Fisher, Public Service Co. of Northern Illinois.

Summary — G. K. Hardacre, President, Chicago Lighting Institute.

The successful clinic was under the direction of Carl W. Zerson, Director, Chicago Lighting Institute and Paul Fisher, Illuminating Engineer with Public Service Co. of Northern Illinois.

A.I.D. Holds 22nd Annual Conference

The twenty-second annual conference of the American Institute of Decorators was held in New York City, March 28 - April 2. Some of the features of the meeting were a theatrical presentation of the decorator at work, called "What's Your Problem"; a slide presentation of national historic and contemporary interiors, "Background to Foreground"; and an exhibition, held in conjunction with the conference—"Decoration, 1953." This last exhibit, open to the public, consisted of a series of new and distinctive room settings and home furnishings displays of the latest trends in interior design.

Research Executives To Tour European Scientific Centers

A party of research executives, representing a number of American industries, is leaving New York April 22, bound for a month's tour of technical and research centers in Italy, Switzerland and France, with the view of utilizing foreign laboratories for their research programs. The tour has been organized by Stanford Research Institute in response to requests that it conduct a program of visits to centers that have been subjects of report by the Institute's International Division.

I.E.S. National Technical Conferences

September 14-17, 1953 — Hotel Commodore, New York
September 12-16, 1954 — Chalfonte-Haddon Hall, Atlantic City
September 12-16, 1955 — Statler Hotel, Cleveland
September 16-21, 1956 — Statler Hotel, Boston.

Michigan Section Participates In Occupational Vision Conference

A full two-day Conference on Occupational Vision was held at Michigan State College, February 26-27, with the Michigan Section of I.E.S. as one of the sponsoring organizations. The program was opened by Clarence D. Omans, Chairman of the Occupational Vision Committee, Michigan Optometric Society and delegates were welcomed by Edgar L. Harden, Director of the College's Continuing Education Service. The program included:

FORUM ON VISUAL EFFICIENCY

Evaluation of the Visual Needs of a Job—Charles S. Pesterfield, Department of Mechanical Engineering, Michigan State College.

Fitting the Worker to the Job—Richard Feinberg, President, Northern Illinois College of Optometry.

Visual Performance and Our Occupations—R. A. Sherman, Bausch and Lomb Optical Company.

Economics of Visual Efficiency—W. J. Heather, Public Relations Department, American Optical Company.

FORUM ON LIGHTING AND COLOR

A. C. Sangster, Detroit Edison Company, Presiding.

Important Concepts in the Use of Lighting and Color—L. E. Tayler, Detroit Edison Company.

Demonstration of Light and Color — E. W. Pratt, Detroit Edison Company.

Color in Industry—J. M. Jokela, Pittsburgh Plate Glass Company.

FORUM ON DEVELOPING VISION PROGRAMS

Ernestine B. Davidson, Detroit Society for the Prevention of Blindness, presiding.

Teamwork in Occupational Vision Programs—Hedwig S. Kuhn, Joint Committee on Industrial Ophthalmology of A.M.A. and A.A.O.O.

Implementing a Workable Vision Program—Panel discussion with H. S. Kuhn, Moderator.

The Driver Testing Laboratory of the Michigan Trucking Association was available for inspection, under the supervision of James B. Spice, Assistant Safety Director of that association.

Score at Half-Way Mark In Membership Campaign

A total net increase of 4.6 per cent for the Society at the half-way mark of the membership campaign is reported by R. G. Slauer, Chairman of the National Membership Committee.

As of February 12, Group I leaders were Northern California Section and Southern California Section with scores of 10.5 and 8.3 per cent respectively. Group II is led by St. Louis Section and Georgia Section with 33.4 per cent and 19.1 per cent to their credit. Out in front in Group III, at the half-way mark, were Indiana Chapter, Florida Chapter and Eastern New York Chapter, 14.7, 14.5 and 13.8 per cent, in that order. Leaders in Group IV are the Mid-South Chapter, 52.0 per cent and New Mexico Chapter, 44.0 per cent.

Chairman Slauer comments, "A good second half can do much to overcome an indifferent first half, just as much as a poor second half can tarnish a first half lead."

Three-Day Conference on Materials To Supplement Industry Exposition

A three-day conference to discuss the wide range of basic materials available will be held at the Hotel Roosevelt, New York City, June 16-18. The conference will supplement the first Exposition of Basic Materials for Industry, Grand Central Palace, New York, June 15-19.

Morning sessions of the meeting will be devoted to the broad, general aspects of material selection, and afternoon sessions will be given over to the technical, engineering considerations of the properties of new and old materials.

One session will be held on the economic factors of new materials already developed and those in the research stage. An effort will be made not only to describe the characteristics of these materials but also to discuss them in terms of availability, comparative costs with competitive materials, their capabilities and methods of selection. Another session will discuss product design with special emphasis on the coordination of materials with production and design, from the standpoint of efficiency in use, sales appeal, cost and the type of machinery used in the manufacturing process.

Other meetings will include the organization and operation of materials engineering departments, the development and use of books specifying standards for materials, use of standards for sizes and composition, sources of information about new materials, and special uses for high strength, and resistance to high temperatures and corrosive elements.

The conference and exposition are sponsored by a board of representatives from over 20 companies, with Don G. Mitchell, Sylvania Electric Products, Inc., as chairman. Theodore C. Du Mond, editor of *Materials and Methods* is serving as general chairman of the conference.

Advance registration cards may be obtained from Clapp & Poliak, Inc., the exposition management, at 341 Madison Ave., New York 17, N. Y.

New Focusing Device for Naval Aircraft Searchlights

An automatic focusing device, developed by D. A. Walsh, W. F. Mullis and T. H. Projector of the National Bureau of Standards photometry laboratory, incorporates novel features greatly improving the simplicity and reliability of Naval aircraft searchlights. The device is an obturator probe.

The N.B.S. obturator probe has a number of advantages over the thermostat-optical system it replaces. It has practically no inertia and functions satisfactorily for the brief periods required of anti-submarine searchlights. Since it is permanently and rigidly attached to the positive head mechanism, there are no adjustments to make and no danger of disturbing any adjustment. It is not easily damaged or rendered inoperative by mechanical shock, vibration, dirt, corrosion or other environmental conditions that may interfere with the operation of thermostat-optical or photoelectric optical systems. Since the obturator probe complete-

(Continued on page 12A)

MARINE LIGHTING Committee as they met at Groton, Conn., recently. L. to r. E. Boghosian, A. Vandervelde, C. L. Crouch, R. L. Sweeney, R. M. Timmins, E. W. Beggs, C. B. Murphy, F. E. Hayden, Dean Farnsworth, C. E. Egeler, and J. Andrews of the Electric Boat Company.

NEW GENERAL ELECTRIC INTRODUCES A BRIGHTER

FIRST INSTALLATION of new Form 206 luminaires was made in December, 1952, by Dayton Power and Light Company, at Oakwood, Ohio. A total of 52 Form 206 luminaires light the city's main business street.

You can put your confidence in—

GENERAL ELECTRIC

FLUORESCENT LUMINAIRE BROADER LIGHT PATTERN

Form 206 Maintains High Light Output Regardless of Temperature Changes

Now General Electric Engineers have made possible the finest whiteways in the world with the development of the new Form 206 Fluorescent Luminaire. Its high light output is held constant throughout a broad range of temperature, maintaining the lighting effectiveness in any weather conditions and throughout all hours of the night. The new six-foot "Rapid Start" G-E fluorescent lamps are designed specifically for outdoor operation. They require no starters, have no starting flicker, and light within a second after being turned on. With its broad, bright light pattern, particularly effective on wet pavements, the Form 206 Fluorescent Luminaire sets an entirely new standard of modern street lighting.

NEW, EASY INSTALLATION. Designed for speed, simplicity, and economy of installation, the Form 206's bracket is an integral part of the fixture. There are no guys, trusses, or supports. The entire unit, including bracket, weighs about 100 pounds, and is less than seven feet long.

NEW MODERN APPEARANCE. Because all wiring can be internal, appearance of the new Form 206 can be free of unsightly wire loops. The Form 206 Luminaire can house its ballast, eliminating pole mounting. Natural aluminum housing and clear plastic globe in sleek, clean design make a dramatic, modern addition to any city's main business streets.

NEW ECONOMICAL MAINTENANCE is assured with lamps rated 7500 hours for long, economical service, and the elimination of starters. A completely enclosing plastic globe minimizes the effect of water, dust and dirt. Hinged at one end, it swings down and remains in position for fast easy servicing, when necessary.

1878 75 1953
YEARS OF ELECTRICAL PROGRESS

FOR MORE INFORMATION contact your nearest General Electric Sales Office or write for Bulletin GEC-963, Section 452-133, General Electric Co., Schenectady 5, New York.

LOW MAINTENANCE COSTS are assured by features designed for rapid, easy servicing. Plastic globe, conveniently hinged, swings down for easy access by workmen. Maintenance costs are also reduced by this enclosing globe which minimizes water, dust and dirt problems. Luminaire is less than seven feet long.

FORM 206 LUMINAIRE is shown mounted on G-E aluminum pole. Sleek luminaire design combined with internal wiring and elimination of external ballast adds beauty to city streets.

THIRD session of the lighting courses sponsored by the Philadelphia Section, I.E.S. and the Spring Garden Institute was completed March 5. A. S. Turner, Jr., was Course Coordinator and A. A. Brainerd is Chairman of the Section's Committee on Education and Student Activities.

(Continued from page 9A)

ly surrounds the positive carbon, its operation is very reliable, even when the arc itself for any reason becomes unstable. Arc instability may result, for example, from defects in carbons or from chipping at the positive carbon tip during striking; such instability interferes with the accuracy of the focus control of any system and in the case of optical systems may result in complete loss of control and damage to the arc mechanism. With the obturator probe, however, control remains effective throughout any unstable period, although there may be some reduction in accuracy. As soon as stability is restored, the control functions as accurately as before.

Plastics Exhibit Goes on the Road

One unit of a "road show," currently touring the United States is a lighting exhibit demonstrating various uses of corrugated acrylic pieces, coffer pans for large area luminaires and luminous ceiling applications. The show is being exhibited in 17 major cities by the Rohm and Haas Co. to demonstrate design techniques and uses developed for their acrylic plastic.

In addition to the lighting exhibit, there is a full scale model store equipped with typical applications of the plastic, such as internally lighted formed letters and pylon panels, corrugated valances, interior partitions, gondola and canopy signs, point of sale signs, merchandise trays and display equipment. The whole exhibit requires a minimum of 1500 feet of floor space.

IT SEEMS TO ME

Calculation of Glare Factors

Since the publishing of a paper on Glare Factors by Ward Harrison and myself in the February 1947 issue of I.E., practically nothing has been written about calculating glare factors. At that time, I was doing it the hard way, without much system; and the word got around that it was a very intricate and long drawn out operation. Since then, a routine based on a standardized layout concept has greatly cut down the time to do the figuring. It is expected that in the near future one of the Nela Park publications will carry an outline of this method. Meanwhile, some fixture manufacturers and testing laboratories have come to Nela Park for instruction in the routine.

The effect of position of a luminaire in the field of view, as described by the term "Location Coefficient" in the 1947 paper, has been somewhat modified as a result of the researches by S. K. Guth (I.E., November 1949). New location coefficients have been applied in the routine of calculation, though a complete set of curves to replace Fig. 2 on page 156 of the 1947 paper has not been drawn up.

In the interest of time saving as well as uniformity of results incorporating the latest data, it is urged that anyone who wants to calculate glare factors get in touch with me beforehand. PHELPS MEAKER, *Lamp Division, General Electric Co., Nela Park, Cleveland, Ohio.*

Light Depreciation Survey

It was interesting to read on page 19A, February issue of I.E., a rather comprehensive discussion by R. D. Burnham of my article on light depreciation, which was published in I.E., August 1952. This discussion, and others partaken in by the writer via phone and letters, shows that some engineers are interested in this important subject.

To insure that Mr. Burnham's effort receives the attention that it deserves, I should like to comment upon some of his statements. It is agreed that quantity plus quality of illumination are prerequisites of good lighting for such seeing tasks as are found in the Roanoke office building [where Mr. Dzwonczyk's survey was made]; and I assure Mr. Burnham that neither was neglected nor was economy overlooked. The intensive economic study and review of data on available fixtures which preceded the lighting design for this building would make an interesting story, but space limitations would not permit it. Suffice it to say that each fixture had to meet the criteria mentioned in the paper, upon which the philosophy of lighting in this building was based. The levels of illumination had to be adequate for the individual work tasks, and no luminaires having brightnesses in excess of two candles per square inch in the glare zone were even considered for intensive study. In short, brightness considerations were not overlooked. *(Continued on page 15A)*

I.E.S. Regional Conferences, 1953

Southwestern	Hotel Baker Dallas, Tex.	April 12-14
Midwestern	Radisson Hotel Minneapolis, Minn.	April 30 - May 1
East Central	Hotel Lord Baltimore Baltimore, Md.	May 14-15
Southern	Sedgefield Inn Greensboro, N. C.	May 18-19
Great Lakes	Syracuse Hotel Syracuse, N. Y.	May 25-26

today's finest fluorescent luminaire

director by Smithcraft

For a truly sound investment of lighting dollars, the Smithcraft Director is in a class by itself! Installed in literally thousands of banks, stores, schools, offices and similar locations across the United States, the Director is actually a "lighting element" that provides highest quality illumination through large unobtrusive **area of light** source. (The eight-foot, six-light Director provides more than 24 square feet of light source.) Here is ideal lighting that blends with overhead architecture without imposing on the eye the dominance of conventional fixture design.

More than just another lighting fixture, the Smithcraft Director, through its distinctive appearance and superior lighting qualities, brings many **plus** values wherever it is installed. In banks, insurance companies and public buildings of all kinds, it lends an atmosphere of substance and dignity; in offices it contributes greatly to efficiency; in stores it adds to the general selling appeal of both the store itself and the merchandise it sells. **There is no finer lighting investment.**

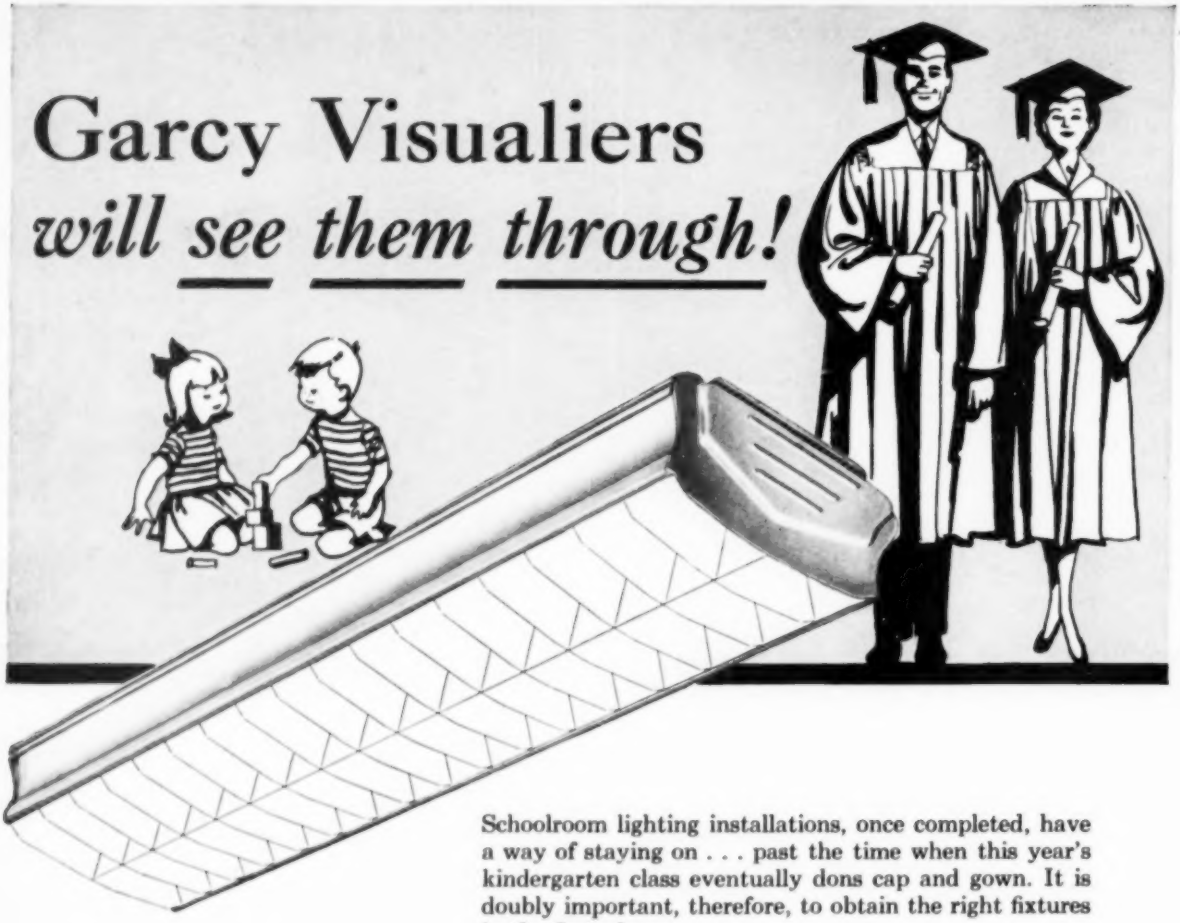
The Smithcraft Director is available in sixteen different units — for Bi-Pin and Slimline Lamps — with louver shielding of 35° crosswise, 25° lengthwise or with deluxe louver shielding of 40° crosswise, 35° lengthwise. There is a unit to fit the needs exactly of any installation.

For evidence of the superior lighting qualities of the Smithcraft Director, send now for the new eight-page Director folder incorporating the results of comparative tests conducted by one of the nation's outstanding utilities, a leader in lighting.

America's finest fluorescent fixtures

Smithcraft
LIGHTING DIVISION
CHELSEA 50, MASSACHUSETTS

Garcy Visualiers
will see them through!

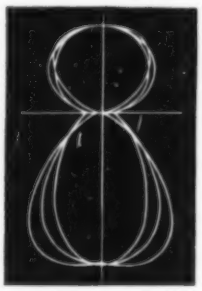


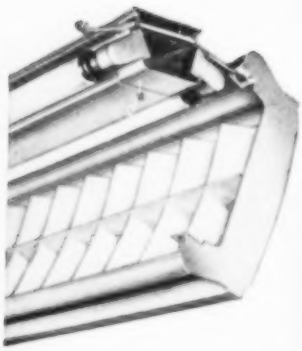
Schoolroom lighting installations, once completed, have a way of staying on . . . past the time when this year's kindergarten class eventually dons cap and gown. It is doubly important, therefore, to obtain the right fixtures in the first place.

Garcy's "Visualier" is eminently qualified. Lighting efficiency far exceeds I.E.S. and A.I.A. school lighting specifications . . . as to light utilization, light distribution, shielding and low surface brightness.

Of equal importance, the "Visualier's" high level lighting efficiency can be readily maintained. The large louver cells are easily cleaned from the floor with a brush or vacuum. All-metal construction means no breakage or warping. Garcy's exclusive one-piece louver design contributes time-defying durability. Detailed literature and E.T.L. data will be sent on request.

Garcy "Visualiers" provide full 45° shielding *plus illuminated side panels.* The "Visualier" Series is available in 2 lamp and 4 lamp units, for 4 ft. standard as well as 4 ft. or 8 ft. slimline lamps.





Louver shield consists of a one-piece stamping . . . an exclusive Garcy development. No rusting of welded parts . . . no loosening due to vibration . . . and far more inherent strength.

GARCY GARDEN CITY PLATING & MFG. CO.

1760 N. ASHLAND AVE., CHICAGO 22, ILLINOIS

(Continued from page 12A)

To correlate the quality of illumination in each room with the light depreciation test data would be a monumental job, if it could be done reasonably. The purpose of this test was not to place so many obstacles in its course that discouragement would prevail, but to devise one which would yield relative light depreciation data with a minimum of effort. The data obtained from these tests may not have the scientific accuracy which could be obtained in a laboratory controlled test; but they do provide information which should help one make a more intelligent guess in the selection of luminaires for a future job than if the data were not available.

Yes, we considered such factors as making use of standard clean lamps in each fixture during successive tests, etc., but it was decided that the work involved would be greater than the incremental value of the greater accuracy obtained. After all, the lamp manufacturers publish lamp deprecaition data which could be used to correct the test data so that only the loss due to dirt on fixtures, walls, ceiling, floor and furniture is included.

It is difficult to see how any luminaire is significantly penalized in this kind of survey, because of the non-cosine response of the Weston 603 meter. Test points in the various rooms (Fig. 1 of the article illustrates only one of the arrangements) were so chosen that both direct and reflected rays would be received by the instrument and at angles as close to the normal as practicable. The observations of all points are averaged and this is compared to the intial observations on a per unit basis. Whatever error is introduced due to the response of the meter surely must be introduced in all successive tests and when the averaged ratios are obtained, any recurring error tends to cancel out. It would seem that the procedure is sufficiently refined to reduce all significant errors to a minimum. After all, this is a practical consideration, not a scientific one, and it would seem that a practical approach should be adequate.

Mr. Burnham's remarks are appreciated because they emphasize the need for depreciation data on lighting fixtures. It is the writer's contention that such data can be readily obtained from any installation but its value will depend upon proper correlation with operating conditions.

Yes, it would be nice to have all the data scientifically perfect, but I think it is more to the point to have the data, imperfect as they may be, than to have none at all. V. L. DZWONCZYK, *American Gas and Electric Corp., New York, N. Y.*

OBITUARY

A. C. Bergh, Charter Chairman of the Southeast Florida Chapter, and continually active Member in furthering the interests of the Society, died last month.

A Local Representative for I.E.S. in Southern Florida since 1937, his efforts culminated in June 1948 in the charter for Southeast Florida Chapter. Active in the promotion of good lighting practice, especially in schools, Mr. Bergh was instrumental in bringing about statewide "Sight Conservation Week" proclaimed by the Governor in 1943 and 1944, and a one-day Fluorescent Lighting School, which was sponsored by the Florida Power and Light Company. The formation of the I.E.S. Student Chapter at the University of Miami was also due, in great part, to his enthusiasm and efforts.

Mr. Bergh had been associated with the Florida Power and Light Company, as Lighting and Seeing Specialist since 1925.

ABOUT PEOPLE

Arthur B. Oday, executive engineer with General Electric Co. in Nela Park, retired March 1. Mr. Oday had been with the company for more than 40 years.

Dr. Aaron M. Hageman, who for the past ten years has directed research and engineering at the Lamp Division of Westinghouse Electric Corp., Bloomfield, N. J., will retire August 31 after 35 years' service with the corporation.

Campbell Rutledge, Jr., has been appointed to the newly created position of assistant general manager of the Electrical Products Division of Corning Glass Works.

The Board of Directors of Day-Brite Lighting, Inc., have announced the appointment of four vice-presidents. **O. W. Klingsick** has been named Executive Vice-President; **James F. Whitehead,** Vice-President in charge of Sales; **O. C. Klingsick,** Vice-President in charge of Operations; and **William S. Coffing,** Vice-President-Controller.

Lawrence W. Auckland has been named manager of the Lake Erie Division of Westinghouse Electric Corp., Lamp Division. Mr. Auckland will have his headquarters in Cleveland.

Harold E. Gumbart has been named western district sales representative for the New Products Division of Corning Glass Works, and will have headquarters in Los Angeles. Mr. Gumbart was formerly senior sales engineer.

John B. Muller has been appointed Eastern regional sales manager of lighting products for Sylvania Electric Products Inc., with headquarters in the company's New York offices.

A new corporation has been formed as distributor in the United States for Imperial Chemical Industries Limited, Plastic Division. The new company is **J. B. Henriques,** Inc., 521 Fifth Avenue, New York City.

Two promotions have been announced by Westinghouse Electric Corp., Lamp Division, Fairmont, West Virginia. **John Bray** has been named assistant superintendent in charge of engineering,

(Continued on page 28A)

Technical Program — Great Lakes Regional Conference

May 25-26 — Hotel Syracuse, Syracuse, New York

1. Evaluation of Fluorescent Lamp Ballasts — Richard D. Bradley, Day-Brite Lighting, Inc., St. Louis, Missouri
2. Lighting the Low-Ceiling Classroom — J. M. Ketch and Carl Allen, General Electric Company, Cleveland, Ohio
3. New Advances in Technical Glass — W. W. Shaver, Corning Glass Works, Corning, New York
4. Maintenance of Industrial Fluorescent Lighting Equipment — Floyd Sell, The Detroit Edison Company, Detroit Michigan
5. A Closer Look at Brightness Engineering — Gene Rae, The Holophane Company, Inc., New York, New York
6. How to Photograph Lighting Installations — Tom Knowles, General Electric Company, Cleveland, Ohio
7. Store Lighting — R. C. Allison, T. Eaton Company, Toronto, Ontario
8. Brightness vs. Illumination for Luminous Ceilings — Robert D. Burnham, The F. W. Wakefield Brass Company, Vermilion, Ohio
9. Street Lighting as Affected by the New American Standard Practice — E. B. Karns and/or D. W. Rowten, Westinghouse Electric Corporation, Cleveland, Ohio
10. Lighting Progress Report — T. C. Sargent, Sylvania Electric Products, Inc., Salem, Massachusetts
11. "My Most Interesting Lighting Job" Contest — Contest Chairman: D. E. Vincent. First and second place Regional winners to be announced.

How Does It Rate?

How good is this installation in terms of quantity and quality of light, brightness ratios, reflectances . . . how does it stack up in all the factors that affect visual comfort?

Illuminating engineers find the answers quickly in the *American Standard Practice for School Lighting.* Sponsored by I.E.S. and the American Institute of Architects, approved by the American Standards Association, this report is one of a series providing basic information on the visual needs of major markets—with recommendations to aid in planning lighting to meet their requirements.

Pocket-sized guides to lighting techniques and helpful yardsticks for gauging the efficiency of each installation, these *Standard Practices* are a practical, daily help to lighting engineers. Thousands of man- and woman-hours were freely given to their preparation by members of the

Illuminating Engineering Society

LPI AREALUX

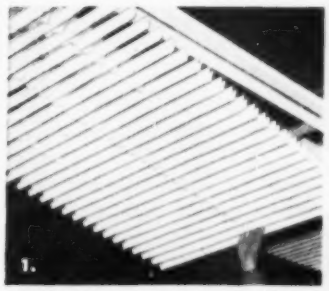
This Arealux fixture is 35¾" wide, 97" long, 5" high. Also available in 48" and 72" lengths; 13" and 18" widths.

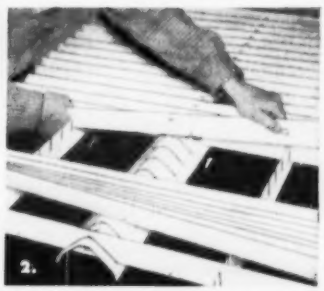
See it – compare it

No other LARGE AREA LUMINAIRE can match these new exclusive features

1. Large area light source, very shallow, highly stylized.
2. Louvers separately removable for cleaning (see below).
3. Completely **self-contained** as a louverall system.
4. Exclusive hanger arrangement provides perfect alignment.
5. Fixtures easily joined endwise or sidewise, or both, for large panels of light. Top reflectors available.
6. Highly efficient used alone or in combinations.
7. Can be surface, suspension or recess mounted.
8. Shipped fully assembled, ready to install at **minimum** cost.
9. Priced comparable to standard width fixtures.
10. Completely wired with E. T. L. and U. L. approved ballasts. U. L. approved and I. B. E. W.—A. F. L. Union Label.

LIGHTING PRODUCTS, INC., Highland Park, Ill.





NEW LOW in cleaning costs. 100% cleanability. **1.** unhinge louver panel—one hand does it! **2.** Lay panel flat on table. Slip out louvers with simple finger pressure. Wipe both sides of blade clean simultaneously with damp cloth. Snap louvers back in—and the job is done!—in about 1/10 the time needed for old-style fixtures.

Lighting Products, Inc., Dept. D, Highland Park, Ill.
Please send me LPI AREALUX BULLETIN #470. I am interested and want to know more, but this request obligates me in no way whatever.

MAIL COUPON NOW

FIRM NAME_____

My Name_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

Engineered by Specialists to meet your needs and specifications

Kopp lenses

EVERY Kopp Glass Lens is *designed* to meet some special set of conditions, *made* to meet exact specifications, and *checked* to assure complete compliance with all requirements.

The specialized knowledge needed for these operations has been developed through many years of specialization in the engineering and manufacturing of lenses. Kopp Laboratories are staffed and equipped to study your requirements and to develop lenses, color filters and roundels that accomplish your objectives. Manufacturing functions are performed by men skilled through long experience in the various operations.

This complete organization is at your service whenever you have a problem involving lighting glassware.

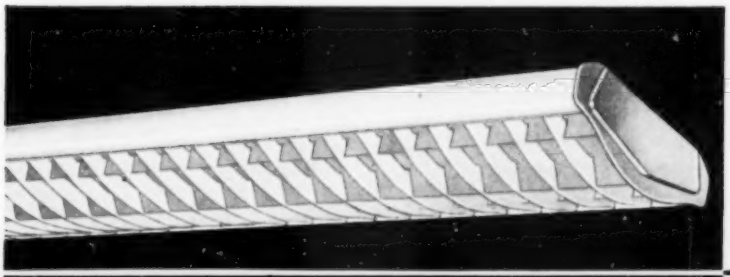
KOPP GLASS

KOPP GLASS, Inc.
SWISSVALE, PA.

new mitchell fluorescent luminaires

with upward component and low cost efficiency

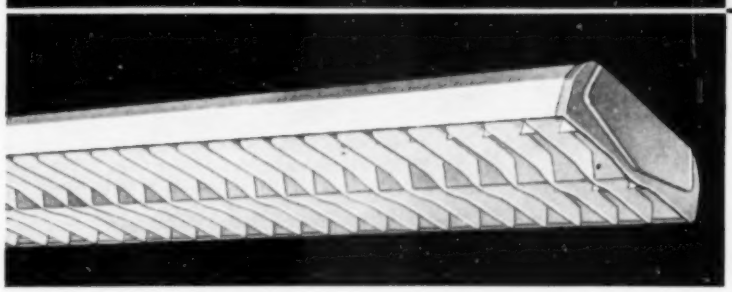
MITCHELL engineering achieves remarkable standards of abundant, glare-free illumination in these new Commercial Luminaires. Important lighting advantages are achieved by the substantial upward component which provides a "general diffuse" lighting effect. The superior louver design delivers properly shielded illumination to the working area. Smooth styling, unusually low maintenance factor and surprisingly low cost make these new MITCHELL Luminaires outstanding values in commercial fluorescent lighting.



the "LODESTAR" luminaires
with translucent plastic sides

4-FOOT MODELS: Available in 2 or 4 lamp luminaires, choice of 40-watt medium bi-pin, 40-watt Instant-Start, 40-watt Rapid-Start, 38-watt Slimline.

8-FOOT MODELS: Available in 2 lamp 75-watt Slimline; 4 lamp or 8 lamp 75-watt Slimline, 40-watt medium bi-pin, 40-watt Instant-Start, 40-watt Rapid-Start or 38-watt Slimline.



the "ECONOMY" luminaires
with metal sides

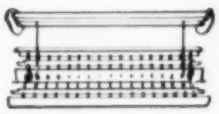
4-FOOT MODELS: Available in 2 or 4 lamp luminaires, choice of 40-watt medium bi-pin, 40-watt Instant-Start, 40-watt Rapid-Start, 38-watt Slimline.

8-FOOT MODELS: Available in 2 lamp 75-watt Slimline; 4 lamp or 8 lamp 75-watt Slimline, 40-watt medium bi-pin, 40-watt Instant-Start, 40-watt Rapid-Start or 38-watt Slimline.

outstanding lighting features and maintenance advantages

These luminaires are of the "General Diffuse" type; approximately half the light goes up to be reflected from ceiling and upper walls to provide comfortable, glare-free, uniform lighting.

New Rapid-Start units offer an unusual advantage: "No starters to replace." Installation of Rapid-Start luminaires slashes maintenance cost by eliminating starter replacement expense.



Two jack chains suspend entire louver and V-spine assembly from fixture body, making relamping easy and substantially reducing maintenance costs. This convenience feature saves time and money.

Sturdy, concealed spring-loaded louver latch instantly releases or engages all-steel louver by snap-in action. Releases with slight pressure of fingers. Simplifies relamping and maintenance.

where quality counts—
SPECIFY MITCHELL

The superbly engineered MITCHELL "Lodestar" and "Economy" luminaires are built to the most exacting standards for easy time-saving installation, for low-cost maintenance, for dependable long-life performance. Where *quality* with sensible initial cost are important considerations—be *sure*—specify MITCHELL. For complete specifications covering these new luminaires, ask for Bulletins 707 and 708.

MITCHELL MANUFACTURING COMPANY
2525 N. Clybourn Ave., Chicago 14, Illinois
In Canada: Mitchell Mfg. Co., Ltd., 19 Waterman Ave., Toronto

MITCHELL

Mitchell Manufacturing Company, Dept. 3-D
2525 N. Clybourn Ave., Chicago 14, Illinois

Send full data on MITCHELL "Lodestar" and "Economy" Luminaires.

Name.....

Firm.....

Address.....

City.....Zone.....State.....

Day-Brite "Close-up" Quality

GIVES YOU EXTRA VALUE

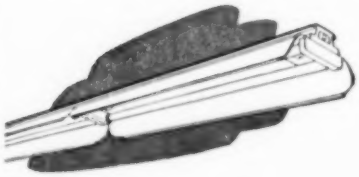
for your plant lighting investment

THIS IS A CLOSE-UP of the aperture in the reflector of a CFI DAY-LINE® industrial lighting fixture. These apertures are *die-embossed*. It would have been easier and quicker merely to stamp them out of the metal. But that would weaken the reflector—take away needed strength. Die-embossing retains strength and improves appearance.

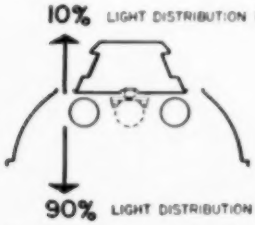
DIE-EMBOSSED APERTURES are Day-Brite's way of giving you up-lighting without sacrificing ruggedness—one of many "close-up" quality features that mean extra value to you.

38

"CFI" means COMFORT FOR INDUSTRY



The CFI DAY-LINE® was designed to make plant lighting comfortable. The more energy a man has to use in seeing, the less he has left to do his work. And if he's bothered by shadows and harsh brightness contrasts, he not only produces less—he's a prime prospect for costly "on-the-job" accidents, too.



The diagram above shows the principle used by the CFI DAY-LINE® to give you more comfortable plant lighting. 10% of the light is directed upward through scientifically placed, die-embossed apertures in the reflector. 90% of the light goes directly down to the work area.

This direct-indirect distribution of light puts an end to dark ceilings and greatly reduces eye-disturbing brightness contrasts.

This greater comfort, plus the many Day-Brite "close-up" quality features —such as vibration-proof Turret* sockets on all units, all-white porcelain enameled reflectors, rust-inhibited parts, wiped reflector edges to eliminate chipping and crazing of the finish — make the CFI DAY-LINE the best industrial lighting value on the market today.

Write for full information. Ask for Bulletin OD-568. Day-Brite Lighting Inc., 5425 Bulwer Ave., St. Louis 7, Mo. In Canada: Amalgamated Electric Corp., Ltd., Toronto 6, Ontario.

*®G. E. Co.

"DECIDEDLY BETTER"
DAY-BRITE
Lighting Fixtures

BRILLIANT PAST...

BRIGHT *Future*

UL CERTIFIED E·T·L

"Past performance" is a good indication of the continued quality of a product. *Certified* ADVANCE BALLASTS' brilliant past is your assurance of superlative achievement and a "Bright Future" for your Fluorescent Lamps. Engineered and Designed by the World's Largest Manufacturer devoted Exclusively to the production of Fluorescent Ballasts.

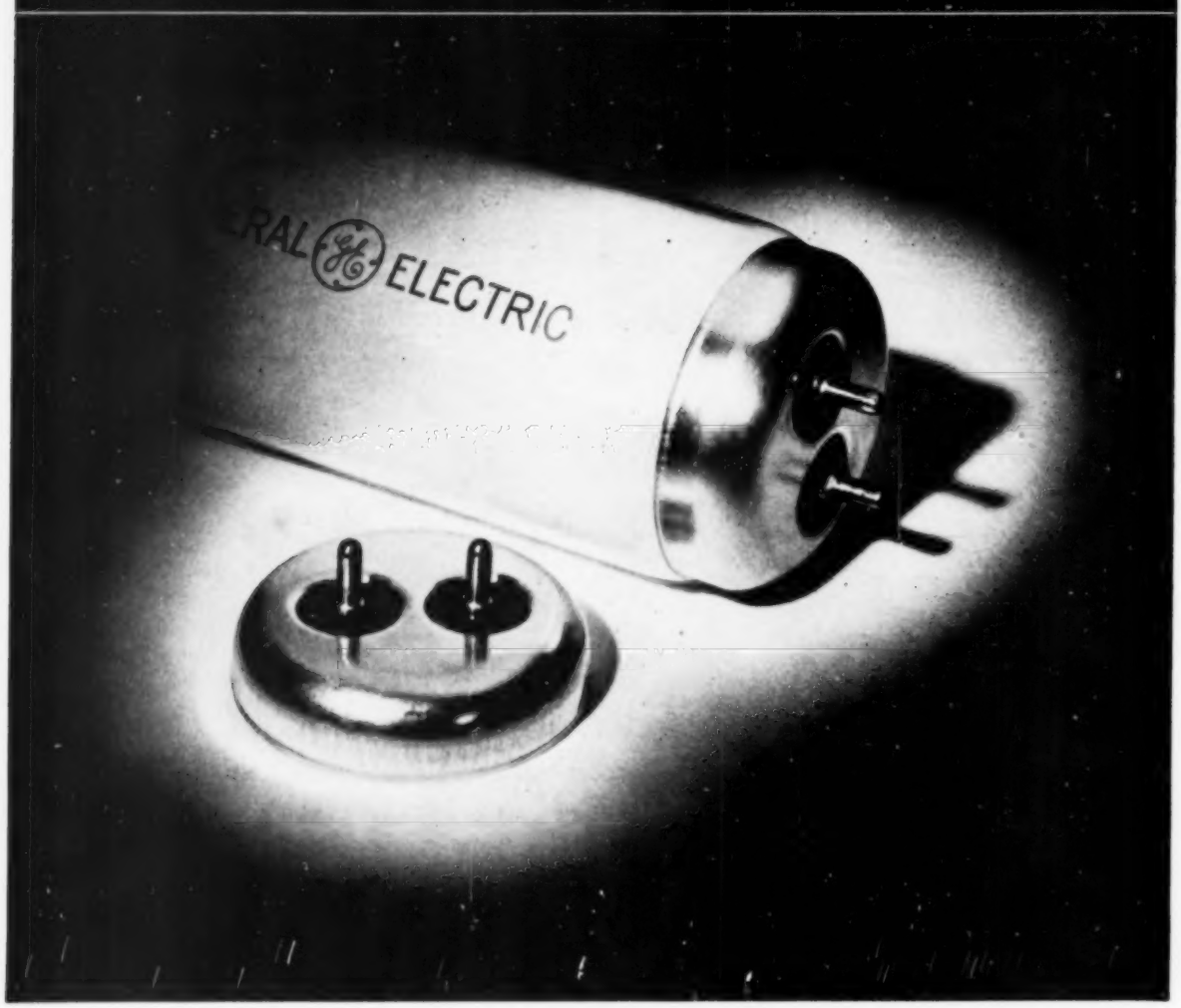
ADVANCE TRANSFORMER CO.

The Best Ballast Buy

CABLE ADDRESS: ADTRANS

1122 W. CATALPA AVE., CHICAGO 40, ILL., U.S.A.

You expect the best value from G-E fluorescent lamps



Rugged aluminum base helps G-E lamps last longer

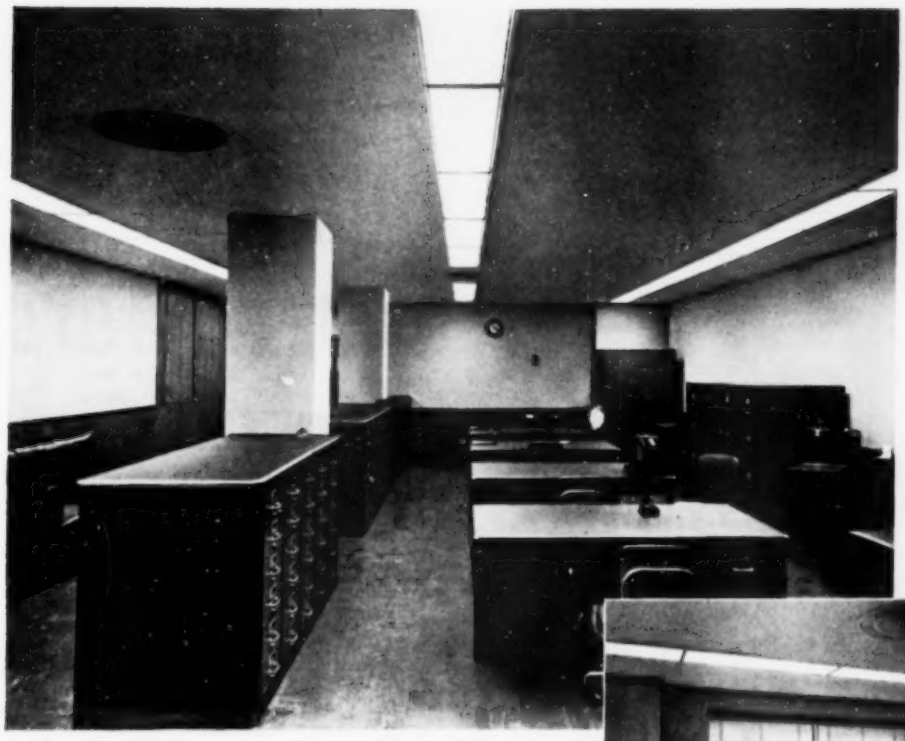
You've probably noticed that G-E fluorescent lamps now have bases made of a white shiny metal, instead of the usual yellow brass or black plastic. It's aluminum.

Aluminum is light and resilient. Won't crack from hard bumps and jolts. Can take the high heats needed to get the best seal between base and glass tube. Doesn't shrink at low temperatures, won't crack the glass tube in cold weather. It helps prevent failure in G-E lamps.

Five years of General Electric lamp research helped make this use of aluminum possible. It shows again why you can *expect* the best value from G-E fluorescent lamps.

You can put your confidence in—

GENERAL ELECTRIC



Treasury Department

Typical Private Office

Easy on the Eyes

...with Lighting by LITECONTROL

Where illumination's concerned sales-minded electric utilities want the best. This one in Kentucky uses two types of standard LITECONTROL fixtures for efficient control of light . . . and smart appearance. Rolled-edge trim helps *hide* uneven spots in ceilings that flat trims only emphasize.

In the executive office, LITECONTROL No. 5134 with Holophane No. 9016 low brightness lens provides ample illumination—free from glare and sharp contrasts.

Easy to maintain. Lenses help keep dirt out. To clean—simply *push trigger-catch*, open door, wipe surfaces with damp rag, and *push door shut*—no tools required.

At left, LITECONTROL fixture No. 5838 is a practical selection for the general office. Rugged, all-metal design provides 35 to 25 degree cutoff from egg-crate louvers . . . holds glare down at critical viewing angles. No tools needed for servicing.

Two more examples of the "More Light and Looks for Your Money" you get with *every* LITECONTROL Fixture.

INSTALLATION: Kentucky Utilities Company, Lexington, Kentucky.
ARCHITECT: Robert W. McMeekin, Lexington, Kentucky.
LIGHTING ENGINEERS: R. W. Wilson, J. T. Cole & K. R. Cordey, Kentucky Utilities Company.
DISTRIBUTOR: Graybar Electric Company, Inc., Indianapolis, Indiana.
ELECTRICAL CONTRACTOR: Hatfield Electric Company, Indianapolis, Indiana.

Treasury Department

FIXTURES: 18 No. 5838, 3-lamp recessed louvered fixtures on 9' centers—standard cool white 96T12 lamps.
INTENSITY: Room average, 90 footcandles.
Desk Tops 75-80 footcandles.

Typical Private Office

FIXTURES: 8 No. 5134, 3-lamp recessed fixtures with No. 9016 lenses on 8' centers—standard warm white 48T12 lamps.
INTENSITY: Room average, 70 footcandles.
Desk Tops, 85 footcandles.

Note: Intensity figures by Kentucky Utility engineers after three months operation.

LITECONTROL
Fixtures
LITECONTROL CORPORATION
36 PLEASANT STREET, WATERTOWN 72, MASSACHUSETTS

DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

Sola Mercury Vapor Lamp Transformers

Regulated or Conventional

for Indoor Lighting Installations

SOLA CONSTANT WATTAGE BALLASTS . . .

. . . continuously and automatically supply constant wattage within ±2% regardless of line voltage fluctuations as great as ±15%. This patented circuit results in the following advantages:

1. *Eliminates need for primary voltage taps*
2. *Assures positive lamp starting*
3. *Reduces line and lamp starting current surge*
4. *Eliminates voltage-drop lamp outages*
5. *Maintains constant lamp wattage, lamp current and light output*
6. *Extends lamp and transformer life.*

Single-lamp and two-lamp units are available for indoor operation of the 400 watt type H-1 mercury vapor lamps.

SOLA CONVENTIONAL-TYPE BALLASTS . . .

. . . are premium quality, non-regulated auxiliaries at moderate prices. They are designed and produced to the same high standards of quality as the Constant Wattage types.

Typical quality features include: the Sola pressed-in-core construction, leads fastened to sturdy lug straps, not merely coil ends . . . high vacuum varnish impregnation . . . pryout in each end cover exposing a ½" threaded conduit fitting . . . ½" and ¾" knockouts . . . large access panels to roomy wiring compartments.

They are available for single-lamp operation of the 400 watt type H-1 mercury vapor lamps. Three primary voltage taps are provided for proper matching to various line voltages, insuring operation at lamp ratings and resulting in full light output.

Write for complete electrical and mechanical specifications

Regulated Outdoor

Regulated Indoor

Conventional Indoor

SOLA *Mercury Vapor Lamp* TRANSFORMERS

Transformers for: Constant Wattage • Fluorescent Lighting • Cold Cathode Lighting • Mercury Vapor Lighting • Luminous Tube Signs

SOLA ELECTRIC CO., 4633 W. 16th Street, Chicago 50, Illinois, Bishop 3-1414 • NEW YORK 35: 103 E. 125th St., Thatcher 4-6464

PHILADELPHIA: Commercial Trust Bldg., Kitty Hawk 5-4948 • BOSTON: 372 Centre St., Newton 58, Mass., Bigelow 4-3354

CLEVELAND 13: 1836 Euclid Ave., Prospect 1-6400 • KANSAS CITY 2, MO.: 404 W. 34th St., Jefferson 4400 • Representatives in Principal Cities

PUBLICATIONS *of the*
ILLUMINATING ENGINEERING SOCIETY

These publications summarize the studies and conclusions of technical committees of the Illuminating Engineering Society over a period of years. They contain the latest available information about many aspects of the art and science of illumination and include details of application as well as lighting technique. Each publication listed here carries the authority and approval of the Society.

These Society publications are available in single copies for information and for lighting reference book shelves or in quantity for educational or other distribution. Each publication is numbered for ordering when using the coupon printed on the back of this page.

(1) I.E.S. LIGHTING HANDBOOK, Second Edition

LATEST! One volume, 987 pages. Published 1952. Complete revision of first edition includes basic information on all phases of lighting practice and technique, based upon recently developed standards. Contains 18 technical reference and application sections; complete appendices of information regularly used; 655 photos, drawings, lighting tables, charts; fully cross-indexed . . . over 4500 items. For use of lighting engineers and specialists, consultants, architects, designers . . . all who plan, install and manufacture lighting systems and equipment.

$8.00 per copy; $6.40 in lots of ten or more. Add 50c for shipment abroad. *I.E.S. Members are entitled to one copy of the Handbook at $5.50 unless previously ordered.*

I.E.S. RECOMMENDED LIGHTING PRACTICES

These booklets contain the latest official I.E.S. lighting recommendations; illustrated with charts and photographs.

(2) HOME LIGHTING Recommended Practice (1947)

(3) OFFICE LIGHTING Recommended Practice (1947)

(4) LIGHTING PRACTICES FOR STORES AND OTHER MERCHANDISING AREAS (1948)

(5) SCHOOL LIGHTING American Standard Practice (1948)

(6) LIBRARY LIGHTING Recommended Practice (1950)

(7) DAYLIGHTING Recommended Practice (1950)

(8) SPORTS LIGHTING Recommended Practice (1951)

(9) INDUSTRIAL LIGHTING American Standard Practice (1952)

(10) STREET AND HIGHWAY LIGHTING American Standard Practice (1953)

Booklets above available at 50 cents per copy or in quantity as follows: first 4 copies, 50c each; next 20, 25c each; all over 24 copies, 15c each.

REPORTS ON LIGHTING IN INDUSTRY

Lighting recommendations based on recent studies (research, surveys of current practice, and experimental installations) of the I.E.S. Committee on Lighting Study Projects in Industry; completely illustrated. Contain analyses of seeing tasks; recommended quality and quantity of lighting; and suitable lighting methods and systems for both general and supplementary lighting.

(11) LIGHTING FOR WOOLEN AND WORSTED TEXTILE MILLS (1946)
Detailed treatment of lighting for opening and grading, carding, spinning, weaving, and perching. Data is also applicable to other types of textile mills.

(12) LIGHTING FOR MACHINING OF SMALL METAL PARTS (1949)
Analysis of factors affecting visibility of convex scales, steel rules, scribed marks, center-punch marks, concave specular surfaces, plane and convex surfaces; general shop lighting; and supplementary lighting for various measuring instruments, bench work, machine tools, and inspection of polished surfaces.

(13) LIGHTING FOR FLOUR MILLS (1949)
Close-up photos of visual tasks and levels and quality of illumination for roll, sifter and purifier floors; packing areas; and product control stations.

(14) LIGHTING FOR CANNERIES (1950)
Recommendations based on committee study and research on general supplementary artificial lighting and daylighting for tasks common to all types of canneries. Also treated are light sources and equipment suitable for installation in canneries; sanitation and safety; and adequate electrical wiring.

(15) LIGHTING FOR BAKERIES (1950)
Committee study report on baking industry; complete with photos and drawings of typical floor arrangements and lighting layouts; paint color for visual environment; use of day lighting; lighting levels for various departments; maintenance. Also use of ultraviolet.

(11) to (15) available at 50c per copy; quantity prices upon request.

OTHER COMMITTEE REPORTS

(16) ART GALLERY LIGHTING (1945)
Completely illustrated guide to lighting exhibits of sculpture and paintings. 50c per copy; quantity prices upon request.

(17) LIGHTING OF CENTRAL STATION PROPERTIES (1951)
Lighting recommendations for control and load dispatch rooms. 50c per copy; quantity prices upon request.

(18) TRANSPORTATION LIGHTING (1951)
Interior lighting for buses, streetcars, rapid transit and railway trains. 25c per copy; quantity prices upon request.

(over)

PUBLICATIONS OFFICE
ILLUMINATING ENGINEERING SOCIETY
1860 Broadway
New York 23, N. Y.

4-53

Date _____

Please send me, addressed as below, copies of I.E.S. Publications which I have indicated by number.
☐ My check (money order) is enclosed. ☐ Bill me.

I.E.S. Section or Chapter

Item No.

_____ copies _____
_____ copies _____
_____ copies _____
_____ copies _____
_____ copies _____

Name _____

Company _____

Street _____

City _____ Zone _____ State _____

Indicate publications wanted by number. Print or type name and address. Clip out and mail.

(19) CONTEMPORARY LIGHTING IN MODERN AND TRADITIONAL INTERIORS (1951)
64 page report combines recommended residence lighting with good decoration techniques. Report written in laymen's language and is completely illustrated. 130 large-scale photographs and drawings show interiors and sketches of construction details using light and color in different home surroundings, Colonial to Modern. Covers both installed luminaires and portables, with separate chapters for cove, recessed, window and wall lighting; ceiling fixtures and wall brackets; portable lamps; use of fluorescent tubes, etc. Available at $1 per copy; quantity prices upon request.

(20) CURRENT LIGHTING PRACTICE FOR TELEVISION PRODUCTION (1951)
Lighting practices currently in use in television studios. 15c per copy; quantity prices upon request.

(21) FUNCTIONAL VISUAL ACTIVITIES IN THE HOME (1951)
Location and extent of the associated areas to be illuminated. Shows by means of dimensioned sketches where representative working planes are located in the home with respect to furniture and lighting equipment. Will aid lighting designers in measuring equipment performance; lighting engineers in lighting installations; home owners in locating portable lamps for optimum illumination. 25c per copy; quantity prices upon request.

I.E.S. LIGHTING DATA SHEETS

Photographs, drawings and engineering data on actual installations. Sheets punched for binders, available on lighting for metalworking, textile, automobile and other industries; schools; stores; offices; drafting rooms; churches; auditoriums; banks; museums; residences; indoor and outdoor recreational areas; street and highway lighting; and other special applications.

Printed on heavy paper, punched for binder, data sheets are an excellent "idea" file for lighting people and architects; ideal for promotional distribution by manufacturers and power companies. Quantity prices upon request.

New 24-sheet Series XVIII should be ordered now for delivery of first 8 sheets soon. Renew your subscription today.

(22) SERIES XVIII—24 sheets
Delivered throughout year; first group of eight (8) sheets available soon; balance in two mailings by February 1954. Subscription $1.25; 10 or more $1 each.

(23) SERIES XIV through XVII—24 sheets each
$1.25 per series; 10 or more $1 each.

(24) HOME LIGHTING DATA SHEET PACKET
Outstanding ideas for lighting various areas in homes—23 sheets—$1.25. Home Lighting Supplement Packet—10 sheets—50c.

(25) SPECIAL DATA SHEET BINDER
New style, durable loose-leaf binder bound in blue fabrikoid and attractively stamped in gold. Single binder $1.50; in lots of 25 or more, $1.25.

LIGHTING COURSE MATERIAL

(26) LIGHTING FUNDAMENTALS
Lithograph outline for a one-semester introductory lighting course suitable for college students or adults. $1 per copy; 10 or more, 75c.

(27) LIGHTING DESIGN PROBLEMS COURSE
(Under revision)

MEASUREMENT OF LIGHT

(28) TESTING PROCEDURES FOR ILLUMINATION CHARACTERISTICS (1948)
Five committee reports in one volume: guides to testing fluorescent lamps and luminaires, and street lighting luminaires. $1 per copy.

(29) FOOTCANDLE SURVEY (IS-10) FOR ARTIFICIAL ILLUMINATION IN INTERIORS 2c per copy.

(30) LIGHTING EQUIPMENT ENGINEERING DATA SHEET
For equipment manufacturers and testing agencies for use as a guide in preparing forms for presentation of photometric and other pertinent data on lighting equipment. Also helpful to equipment purchasers as basis for required data. 10c per copy.

(31) GUIDE FOR PHOTOMETRIC TESTING OF FLOODLIGHTS OF 10 TO 160 DEGREES TOTAL BEAM SPREAD (1951) 90c per copy.

(32) GUIDE FOR OUTDOOR ILLUMINATION TESTS
25c per copy; quantity prices upon request.

NEW REPORTS AVAILABLE SOON

Recommended Practice For Supplementary Lighting

Lighting For Steel Mills, Part I—Open Hearth

Lighting For Pin Drafting and Three Blade Shears

Lighting For Foundries

Date of availability indefinite. Orders placed now will be held pending.

Skylike SOLVES A LIGHTING PROBLEM

at the

SHERATON CADILLAC

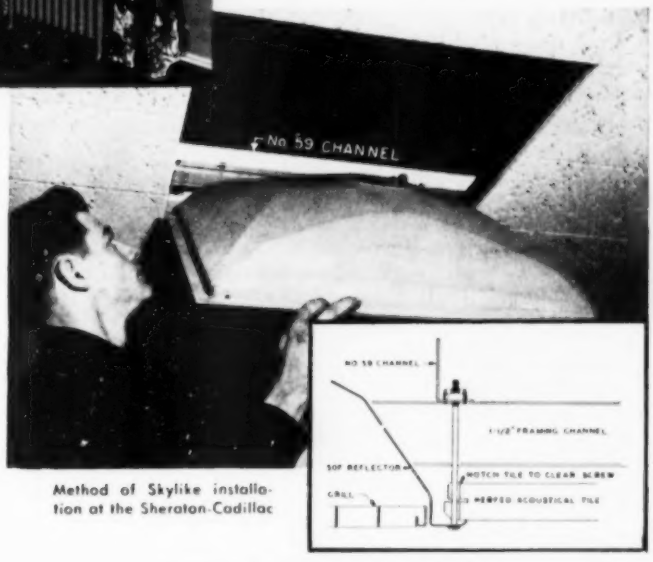
Bedroom suite at the Sheraton-Cadillac using Skylike units

THE PROBLEM . . .

Major renovations of this famous hotel involved air conditioning for the guest rooms. To complete the modernization acoustical ceilings were installed. Hotel management wanted recessed lighting units which would harmonize with any decorative scheme and provide comfortable well diffused illumination.

THE SOLUTION . . .

Recessed SKYLIKE incandescent units using 200W lamps were chosen and installed in the new hung ceiling construction. Sheraton-Cadillac engineers developed a special mounting device for the reflectors which would allow them to be supported from the ceiling framing members without need of bolts or other fastening devices. This permitted adjustment and alignment of fixtures after acoustical panels were installed. (See insert)



Method of Skylike installation at the Sheraton-Cadillac

Skylike ...

This modern, versatile unit can solve your lighting problems as successfully as it has in countless installations throughout the country in . . .

DEPARTMENT STORES
OFFICE BUILDINGS
HOUSING DEVELOPMENTS
SCHOOLS, ETC.
RETAIL STORES
THEATRES
BANKS

SKYLIKE
A SILVRAY-ASSOCIATED COMPANY

SEND FOR COMPLETE DETAILS

A comprehensive 8-page booklet describing the SKYLIKE system and its simple installation is yours for the asking. To get your free copy, fill in and mail the coupon below.

SILVRAY Lighting, Inc., 101 West Main St., Bound Brook, N. J.

Gentlemen:

Please send me complete information on Silvray **SKYLIKE**

Name _____

Firm _____ Title _____

Address _____

City _____ Zone _____ State _____

(Continued from page 15A)

manufacturing and maintenance in the plant's sealed beam section and **Norman Rukin** is to be in charge of lamp engineering in the fluorescent section.

Announcement has been made by Acme Electric Supply Co., Montreal that the company has acquired a 50 per cent stock interest in Tru-Lite, Ltd., also of Montreal. The new officers of Tru-Lite are **C. H. Bunch**, President; **Omer Trudel, Vice-President**; and **Eugen Meth**, Secretary-Treasurer.

Ruby Lighting Corp., Los Angeles, Calif., announces the appointment of **Milton A. Weiner** as Sales Manager.

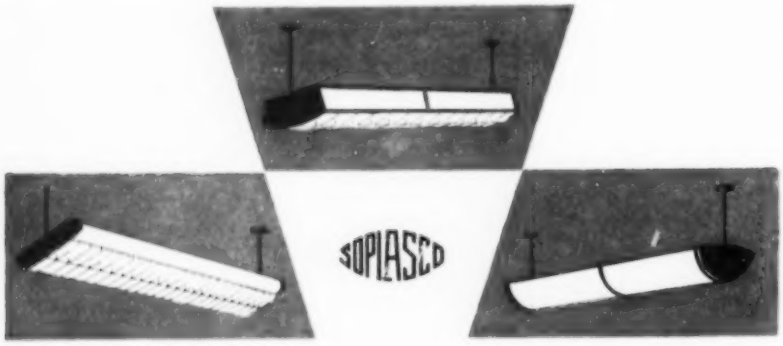
The Pittsburgh Reflector Co. has appointed several district representatives. **A. E. Grawemeyer** has been named for the Arkansas-Tennessee-Mississippi area with headquarters at 3827 Chickadee Ave., Memphis, Tenn. **Verne LaSalle** and **Robert Greenleaf** will represent the company in Cleveland and surrounding territory, with headquarters at 8905 Lake Ave., Cleveland. **Edward C. Muller** has been added to the New York sales staff to handle fluorescent and incandescent lighting sales and engineering. **Bennett H. Williams** is now the representative for middle and southern West Virginia, eastern Kentucky and southern Ohio; with his office at 815 Fourth St., Huntington, West Virginia.

Joseph G. Lipkins, Executive Vice-President of the Broadway Maintenance Corp., New York City, was elected Vice-President and Director of the National Electric Sign Association.

The Miller Company's Illuminating Division has appointed two new lighting salesmen. **Fred B. MacRae** will cover Ohio (except Cleveland), southern West Virginia, eastern Kentucky and southern Michigan, with headquarters in Columbus, Ohio. **James B. Proctor** will represent the company in western Tennessee, western Kentucky, northern Mississippi and Arkansas, with headquarters in Memphis.

The L. Morris Landers Company, Atlanta, Ga., representatives for Electro Silv-A-King, announces the appointment of **Perry G. Sessoms, Jr.**, to assist architects, engineers, and electrical contractors in selecting lighting equipment.

Burnside R. Value, of the engineering firm of Seelye, Stevenson, Value and Knecht, has been elected president of th New York Association of Consulting Engineers, an organization representing about forty engineering firms in the New York area.



PLASTIC PANELS

Southern Plastics Company stands ready at all times to work with your designers and engineers.

Southern Plastics is equipped to develop an extrusion or mold to your specifications or to design the extrusion or mold to fit your needs, as they have done for the largest lighting fixture manufacturers in the world.

SOUTHERN PLASTICS Co.

408 Pendleton St. Columbia, S. C.

BOOKS AND PAMPHLETS

Night Visibility, Highway Research Board Bulletin 56 is an 82-page booklet (publication 236) published in 1952 by the National Research Council, Washington 25, D. C. The papers, presented at the January 1952 annual meeting of the Highway Research Board, are as follows:

"Determination of Windshield Levels Requisite for Driving Visibility" by Warren M. Heath and Dan M. Finch reports the results of a study to determine the extent of glazed areas necessary for driving visibility. Data on current passenger cars are given showing areas available for seeing by all but the tallest 2½ per cent and all but the shortest 2½ per cent of drivers. The dimensions and technique for checking windshields to establish a level that will include 85 per cent of the drivers is given. This percentage was tentatively agreed upon by the Engineering Committee of the American Association of Motor Vehicle Administrators in June 1951.

"Effect of Exposure to Sunlight on Night Driving Visibility" by R. H. Peckham presents data relating to the use of sun glasses. Data presented show that exposure to sunlight during the day results in loss of seeing ability at night under low levels of illumination. Use of sun glasses during the day "effectively prevented this loss." Difficulties in measuring visual acuity at low contrast and low brightness lead to the use of critical flicker frequency, under standard conditions of brightness to measure retinal sensitivity.

"Effect of Pattern Distribution on Perception of Relative Motion in Low Levels of Illumination" by Harold I. Stalder and A. R. Lauer describes a study designed to test the primary hypothesis that driving speed is a factor in discrimination of relative motion in low illumination. Apparatus included a scotometer, described in a previous paper by Stalder, Hoppe and Lauer, which consists essentially of a dark tunnel approximately 43 feet long, having two moving belts painted a neutral gray to resemble a concrete roadway. Miniature cars and tail-gate panels were used to simulate roadway conditions. Data were analyzed on the basis of (1) perception time, (2) estimation of speed differential, (3) estimation of distance, (4) judgment of difficulty, and (5) errors made in direction of movement. Measurements were made with various test panel designs, reflectorized and nonreflectorized at varying speeds and speed differentials.

"Vision at Levels of Night Road Illumination" by Oscar W. Richards de-

scribes experimental findings relating to seeing under levels of illumination customarily encountered on the highway at night. Automobile driving at night is done in illumination of about 3025K with a brightness range of about 4 to 0.003 footlamberts. Within this range human visual power decreases in acuity, contrast, form perception, stereoscopic depth perception, ability to judge size, motion and position and compensation to visual stimuli. The author discusses, along with the illumination range of night driving, problems of dark adaptation, colored glasses, acuity and contrast, speed of vision, specific factors relating to the eye, night myopia, aniseikonia, general factors such as age and sex, glare, and other special conditions.

The fifth paper, by James H. Havens and Allie C. Peed, is entitled "Sperical Lens Optics Applied to Retrodirective Reflection."

Planning the Modern Home Electrically, is a 20-page manual giving practical step-by-step instructions on planning kitchens and laundries. Also included is design information on such home lighting developments as cove, cornice, valance, recess, pinhole spot, and automatic lighting for closets. There is also information on planning an adequate wiring system for the home: where to locate outlets, how many and what kind of circuits to provide for, and how to plan a service entrance. A free copy of "Planning the Modern Home Electrically, B-5853," may be obtained from Better Homes Bureau, Westinghouse Electric Corp., P. O. Box 237, Pittsburgh 30, Pa. (Quantity price $4.50 per hundred.)

The Story of Johnny One-Light and Mary Even-Glow is a picture-story book designed for boys and girls of from eight to ten years. Written by Edythe Polster, consultant on home and school lighting, the booklet is intended to educate children in forming good lighting habits early. The colorful illustrations by John Hapgood and direct simple text should make this dose of education easy to take for children. Single copies at 25 cents are available from Children's Book and Record of the Month Club, Inc., 127 E. 56th St., New York 22, N. Y. Quantity orders at 18 cents per copy should be placed with Miss Edythe Polster, 55 E. 10th St., New York 3, N. Y.

Application of Electrical Equipment in Commercial Establishments, a handbook designed to help the commercial salesman make "on the spot" recommendations and estimates in preliminary form has been made available by Edison Electric Institute. Prepared by the Market Development and Electrical Applica-

(Continued on page 32A)

Did you ever notice

Weatherproof Jefferson Transformer with pole-top adaptor fits any pole 2½" to 4" O.D. Transformer case is heavy deep drawn steel—hot-dipped galvanized for many years of positive protection. No seams or crimped edges for moisture to seep in. Harmonizing Dura-Gray finish for attractive installations.

People Stop To Shop Where Lights Are Brightest ?

Bright lights mean safety and convenience. Lighting men and business men recognize its value wherever people shop, work, or move at night. It's good business to light up.

And it's good business for you to recommend Jefferson Mercury Lamp Transformers and quality built fixtures for top-notch performance as in the parking lot illustrated above.

In every mercury installation it pays to use Jefferson Transformers. You get better lighting results, better appearance, maximum efficiency and lower maintenance costs. Write for your copy of 16 page Bulletin 521-5 giving details of both indoor and outdoor type Jefferson Mercury Lamp Transformers.

And People *Buy* Where Lights Are Brightest ?

In stores, banks, schools and offices, maximum fluorescent lighting satisfaction depends greatly on good ballasts.

Maximum light output, lamp life and dependable quiet operation are assured when you specify Jefferson Ballasts. There's a better built Jefferson Ballast, normal or high power factor design, to operate every standard size of fluorescent lamp. One and two lamp high power factor ballasts for all types and sizes of Slimline Lamps. Included in the line are Series Sequence and Lead-Lag designs. All are E.T.L. and U.L. approved. Write for new Ballast literature.

JEFFERSON ELECTRIC COMPANY
Bellwood, Illinois

JEFFERSON ELECTRIC

Jefferson ELECTRIC COMPANY

the PFAFF & KENDALL story at Seaside Heights, N. J....

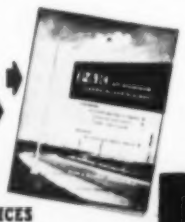
With the rolling Atlantic on one side and picturesque Barnegat Bay on the other, it's no wonder this quarter-mile wide peninsula is so popular with vacationists during summer months. Sun... and sea air heavy with salt and iodine... calm the tensions of thousands of city dwellers every season!

But calm becomes calamity to the ordinary light pole when salt, iodine, high winter winds and frequent storms combine. Damage, maintenance and replacement costs become excessive ... needlessly!

The P & K installation three years ago along the Barnegat Bay Bridge area has required not one penny's worth of maintenance! The P & K All-Aluminum Standards and Brackets are in good condition and appearance... despite the hurricane of November, 1950, which struck with great severity along the Atlantic Coast.

P & K All-Aluminum lighting standards and brackets, 30 ft. high, installed with mercury vapor luminaires on New Jersey seacoast Route 37, Seaside Heights, N. J.

WRITE FOR LATEST P & K CATALOG... AND USE THE P & K PLANNING AND ADVISORY SERVICES WITHOUT OBLIGATION



Pfaff & Kendall
84 Foundry Street
Newark 5, New Jersey

order Sunbeam
incandescent fixtures
for precise
illumination control

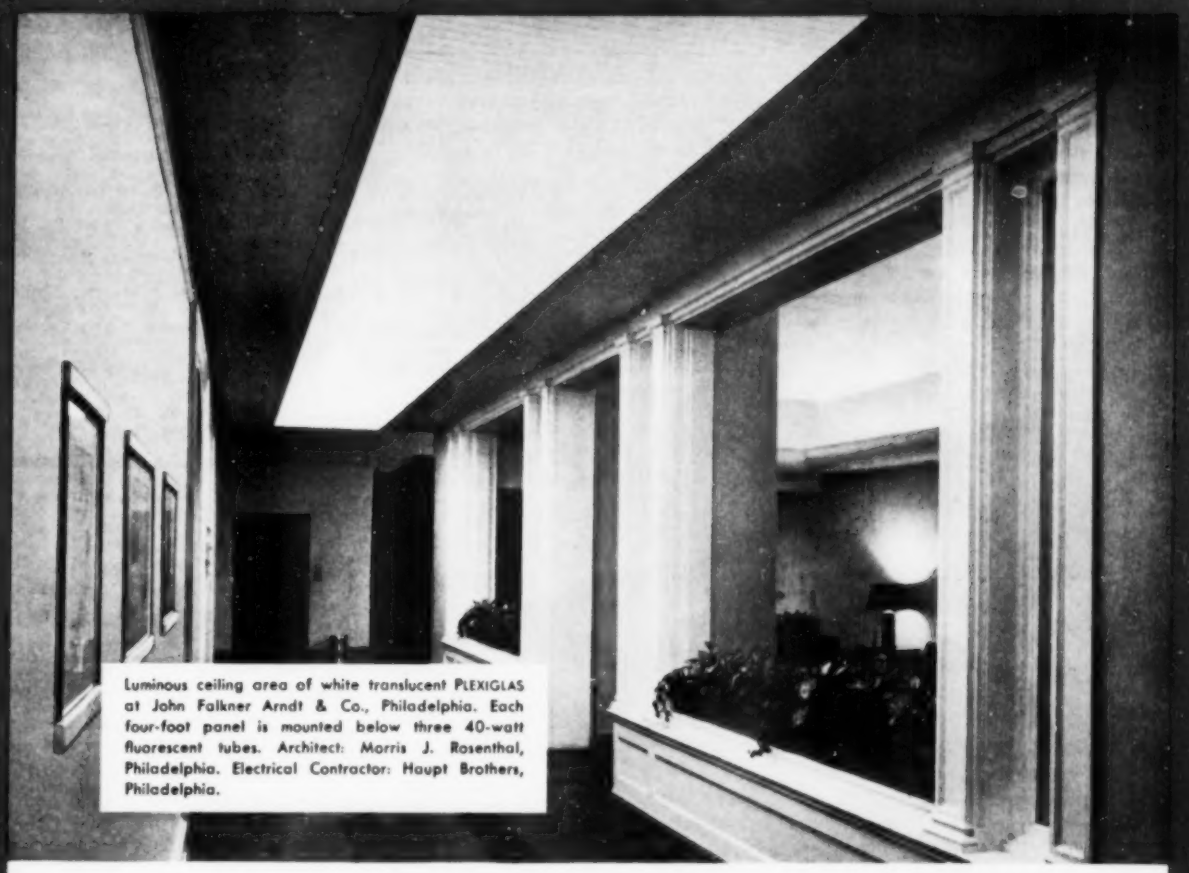
#60101-J. prewired with junction box

Sunbeam's new, recessed incandescent line of fixtures incorporate Holophane Controlens* elements to produce controlled illumination in restaurants, stores, offices, public buildings and other areas where moderately high levels of warm-tone lighting is required. Greatly enhancing the appearance of neatness to the installation, the lens frame and outside trim, each, are made in one piece, heavy gauge, die-formed steel with no welded joints and finished in lustrous silvertone. Various shallow and deep models are available for diverse installation conditions and lighting requirements.

SUNBEAM LIGHTING COMPANY
777 E 14TH PLACE LOS ANGELES 21, CALIF.

SUNBEAM visionaire LIGHTING CONTROL

*@Holophane Co



Luminous ceiling area of white translucent PLEXIGLAS at John Falkner Arndt & Co., Philadelphia. Each four-foot panel is mounted below three 40-watt fluorescent tubes. Architect: Morris J. Rosenthal, Philadelphia. Electrical Contractor: Haupt Brothers, Philadelphia.

For Fixture-Free Appearance...PLEXIGLAS

Corrugated panels of white translucent PLEXIGLAS, mounted as part of the ceiling beneath fluorescent tubes, are important to the inviting appearance of this entrance area in a Philadelphia office.

Notice how the built-in luminous area is in keeping with the clean design of the lobby. Evenly diffused illumination with low source brightness is spread over the entire length of the corridor, without a succession of hanging fixtures that would mar the symmetry of the room design. Because the PLEXIGLAS acrylic plastic panels diffuse completely the light from the concealed lamps, the effect is one of daylighting, as if the ground-floor area were skylighted.

As a diffusing medium, PLEXIGLAS offers other advantages. Rigid, strong, light in weight, it can be handled easily and safely during installation, cleaning and relamping. And because it resists breakage and discoloration, it gives long, trouble-free service.

If you're interested in better lighting, investigate the possibilities of luminous ceilings and lighting fixtures of PLEXIGLAS. We'll be glad to send you our brochure, PLEXIGLAS FOR LUMINOUS CEILINGS.

PLEXIGLAS is a trademark, Reg. U.S. Pat. Off. and other principal countries of the Western Hemisphere.

CANADIAN DISTRIBUTOR: *Crystal Glass & Plastics, Ltd., 130 Queen's Quay at Jarvis Street, Toronto, Ontario, Canada.*

PLEXIGLAS is listed in Sweet's Architectural File, Section 6d/Ro.

CHEMICALS FOR INDUSTRY

ROHM & HAAS COMPANY

WASHINGTON SQUARE, PHILADELPHIA 5, PA.

Representatives in principal foreign countries

(continued from page 29A)

tions Committee of E.E.I., the handbook consists of six sections on the following: classifications of business, commercial air conditioning, commercial ventilation, commercial water heating, commercial cooking and commercial lighting. The handbook is printed on standard 6⅞ x 3⅝ inch loose leaf sheets for insertion in a pocket-size binder. Single copies are available from the Edison Electric Institute, 420 Lexington Ave., New York 17, N. Y. at a price of $1.00 per copy for E.E.I. members and $2.50 per copy for non members.

NEW MEMBERS

At the meeting of the I.E.S. Council Executive Committee, held in New York City, March 12, the following were elected to membership.

ALABAMA CHAPTER

Members:
Lacefield, W. R., J. L. Phillips, Birmingham, Ala.
Mosley, H. D., Mosley and Yarbrough, Montgomery, Ala.
Roberts, Hugh, Alabama Power Co., Birmingham, Ala.

Associate Members:
Brown, R. B., Alabama Power Co., Birmingham, Ala.
Burch, H. S., Noland Co., Inc., Montgomery, Ala.
Burel, J. A., Matthews Electric Supply Co., Birmingham, Ala.
Davis, E. S., Jr., General Electric Co., Birmingham, Ala.
Dorman, H. A., Alabama Power Co., Birmingham, Ala.
Flournoy, L. Q., Alabama Power Co., Birmingham, Ala.
Jackson, D. M., Moore Handley Hardware, Birmingham, Ala.
Keyser, J. T., Alabama Power Co., Birmingham, Ala.
Martin, W. C., Jr., Alabama Power Co., Birmingham, Ala.
Traylor, D. W., Jr., Canterbury Electric Co., Birmingham, Ala.
Truss, W. H., Alabama Power Co., Birmingham, Ala.
Weil, L. J., Mayer Electric Supply Co., Inc., Birmingham, Ala.

CAPITAL SECTION

Member:
Cornbrooks, C. W., U. S. Department of Commerce, Washington, D. C.

Associate Members:
Davidson, J. D., General Electric Co., Washington, D. C.
O'Daniel, C. E., Potomac Electric Power Co., Washington, D. C.

CAROLINAS SECTION

Associate Members:
Locke, J. W., Jr., General Electric Supply Corp., Charlotte, N. C.
Curtis, E. J., Southern States Supply Co., Charlotte, N. C.
Kelly, R. E., Westinghouse Electric Corp., Charlotte, N. C.
Marshall, R. C., Jr., 401A Wakefield Drive, Charlotte, N. C.
Merritt, Brevard, Mill Power Co., Charlotte, N. C.

CENTRAL ILLINOIS CHAPTER

Associate Member:
Webb, R. D., Springfield Electric Supply Co., Bloomington, Ill.

CENTRAL NEW YORK SECTION

Associate Member:
Ladouceur, R .D., City Electric Co., Inc., Syracuse, N. Y.

CHICAGO SECTION

Associate Members:
Brim, Norman, Garden City Plating & Mfg. Co., Chicago, Ill.
Ferguson, W. C., Jefferson Electric Co., Bellwood, Ill.
Fernau, R. M., C .B. Thorsen Co., Chicago, Ill.
Fowler, H. C., Kimble Glass Co., Chicago, Ill.
Harmon, V. M., McCarville Electric Supply Co., Oak Park, Ill.
Jervis, Wayne, Weber Costello Co., Chicago Heights, Ill.
Rhodes, J. F., Sears Roebuck Co., Chicago, Ill.
Stover, D. F., Acme Electric Corp., Chicago, Ill.

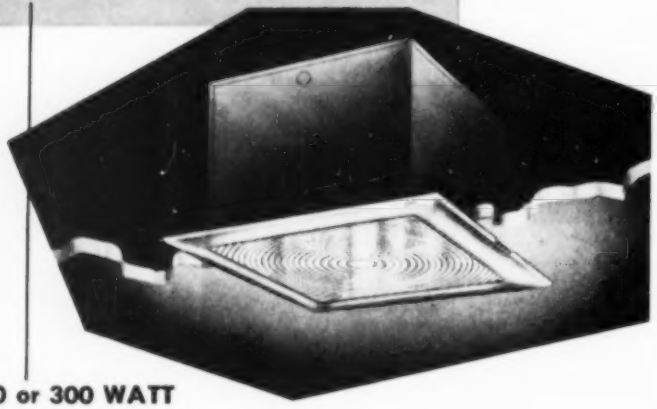
Student Members:
Fairbanks, K. E., University of Illinois, Urbana, Ill.
Hessler, Joan, University of Illinois, Urbana, Ill.
Larsen, P. W., University of Illinois, Urbana, Ill.
Needham, J. E., University of Illinois, Urbana, Ill.

CLEVELAND SECTION

Member:
Linsday, E. A., General Electric Co., Cleveland, Ohio.

Associate Members:
Heran, W. J., Cleveland Electric Illuminating Co., Cleveland, Ohio.
Lyons, B. M., Cleveland Electric Illuminating Co., Cleveland, Ohio.
Martin, Dene, Unique Services, Cleveland, Ohio.
Will, A. J., Midland Electric Co., Cleveland, Ohio.

a **new** departure in design and appearance



200 or 300 WATT

SQUARE **RECESSED DOWNLIGHT**

- Square, silver-mirrored Permaflector, lamp and lens positioned for maximum efficiency with controlled brightness.
- Choice of extensive distribution, intensive distribution and drop bowl lens.
- Designer styled one-piece die-cast frame with concealed hinges and latch.
- Inconspicuous finger-pull for easy opening and maintenance.
- A readywired "packaged" unit with many labor saving installation features.
- Designed to recess into a 12" accoustical module.

Write for Specification Sheet

PITTSBURGH REFLECTOR COMPANY

411 OLIVER BUILDING, PITTSBURGH 22, PA.

FLUORESCENT "Pittsburgh" Permaflector INCANDESCENT

Lighting

REPRESENTATIVES IN PRINCIPAL CITIES • WHOLESALERS EVERYWHERE

CORNHUSKER CHAPTER

Associate Members:
Grimes, W. B., General Electric Co., Omaha, Neb.
Lewis, K. W., Electric Engineering Co., Sioux City, Ia.

EASTERN PENNSYLVANIA SECTION

Associate Member:
Robinson, H. L., Westinghouse Electric Supply Corp., Allentown, Pa.

MARITIME CHAPTER

Associate Members:
McLaughlin, Robert, University of New Brunswick, Fredericton, N. B.
Rice, R. W., Canadian General Electric Co., Ltd., St. John, N. B.

MICHIGAN SECTION

Associate Member:
Fuller, E. C., Electric Wholesale Supply Co., Jackson, Mich.

MID-SOUTH CHAPTER

Associate Members:
Orsburn, A. M., Arkansas Electric Co., Little Rock, Ark.
Wallace, W. E., Shelby Electric Co., Inc., Memphis, Tenn.
Student Member:
Cook, C. H., Southern College of Optometry, Memphis, Tenn.

MILWAUKEE SECTION

Associate Members:
Brandt, N. A., Northern Light Co., Milwaukee, Wis.
Brenne, Marilyn, 806 Marshall St., Manitowoc, Wis.
Zass, J. H., Zass Electric, Waukesha, Wis.

MOTHER LODE CHAPTER

Associate Members:
Cannon, J. K., Pacific Gas and Electric Co., Sacramento, Calif.
Matthews, R. W., 2412 Meadowbrook Rd., Sacramento, Calif.

NEW ENGLAND SECTION

Associate Member:
Fletcher, R. D., Jr., Sylvania Electric Products, Inc., Worcester, Mass.

NEW ORLEANS SECTION

Associate Member:
Corales, F. J., Nu Lite Inc., New Orleans, La.

NEW YORK SECTION

Members:
Gero, W. B., Westinghouse Electric Corp., Bloomfield, N. J.
Michael, Louis, Consolidated Edison Co. of New York, New York, N. Y.
Segmond, Ferdinand, Consolidated Edison Co. of New York, New York, N. Y.
Snook, S. D., Consolidated Edison Co. of New York, New York, N. Y.
Stein, E. M., Consolidated Edison Co. of New York, New York, N. Y.
Associate Members:
Doller, Samuel, Optometrist, 1690 Lexington Ave., New York, N. Y.
Fiorillo, J. J., Consolidated Edison Co. of New York, New York, N. Y.
Frank, L. I., Lustra Corp. of America, Brooklyn, N. Y.
Fredericks, L. M., International General Electric Co., New York, N. Y.
Gillen, G. J., Consolidated Edison Co. of New York, New York, N. Y.
Jones, W. D., Westinghouse Electric Corp., Bloomfield, N. J.
Murphy, R. J., Consolidated Edison Co. of New York, New York, N. Y.
Schroeder, H. E., Consolidated Edison Co. of New York, New York, N. Y.
Wernert, N. E., Consolidated Edison Co. of New York, New York, N. Y.
Wilson, C. W. S., III, The Austin Co., New York, N. Y.

(Continued on page 34A)

More Light with Same Power Load — Plus

INDOOR OUTDOOR
High or Low Bay Installation

No Dirt-catching Reflectors

200 to 1000 Watts
St'd. or High Voltage

HARD GLASS
Won't crack due to sudden temperature changes, moisture, and flying insects.

LOW MAINTENANCE
No reflectors to clean. Higher light output maintained throughout life of lamp with sealed-in silver reflector.

LOW COST INSTALLATION
Only simple socket required for high or low bays. Uses light-weight, low-cost weatherproof outdoor lamp holders.

Send for Technical Bulletin 80

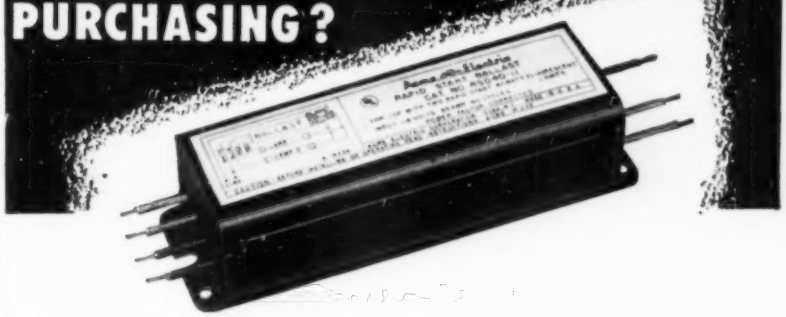
NICKEL PLATED BASE
WEATHERPROOF HARD GLASS
SILVER REFLECTOR INSIDE STAYS BRIGHT ALWAYS
MAXIMUM LIGHT OUTPUT • WIDE BEAM

RADIANT
HI-FLOOD
Reflector Weatherproof
FLOODLAMPS

RADIANT LAMP CORPORATION, 300 Jelliff Avenue, Newark 8, N. J.

Manufacturers of Lamps for PROJECTION • FLOODLIGHT • SPOTLIGHT • MOTION PICTURE PRODUCTION SOUND REPRODUCTION • AERONAUTICAL • SPORTS LIGHTING AND GENERAL SERVICE • RECTIFIER BULBS

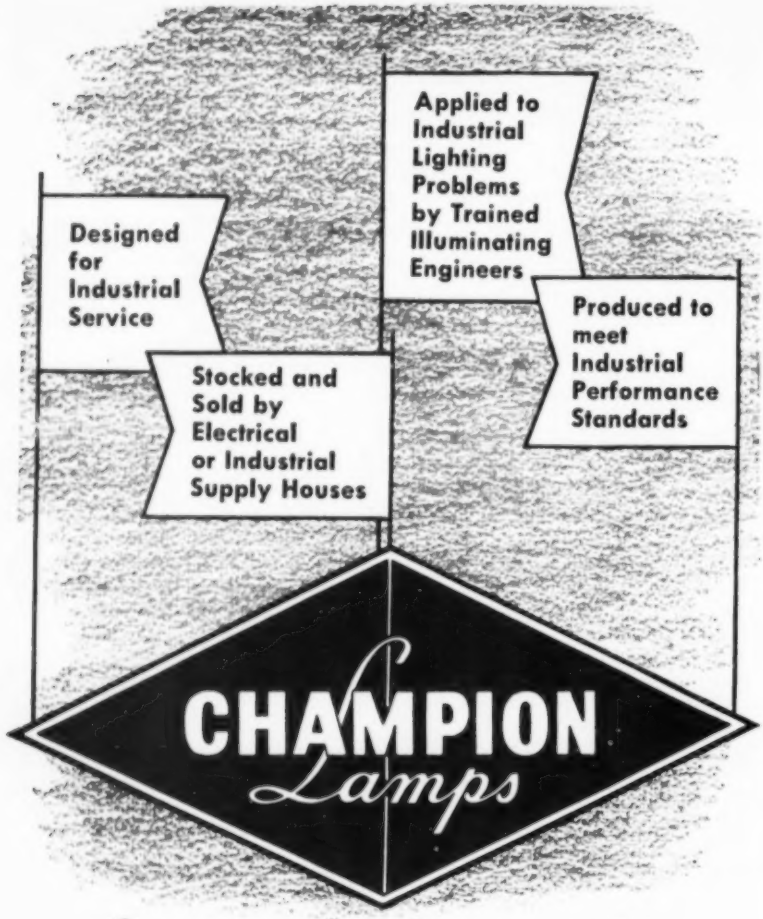
DOES PERFORMANCE INFLUENCE YOUR PURCHASING?



• We offer this ballast to quality buyers, entirely on a "performance test" basis. The price is based entirely on our economical cost of producing quality ballasts in large quantities.

ACME ELECTRIC CORPORATION
294 WATER STREET CUBA, N. Y.
In Canada: ACME ELECTRIC CORP., LTD. • 50 N. Line Rd. • Toronto, Ontario

Acme ACME Electric
TRANSFORMERS


Applied to Industrial Lighting Problems by Trained Illuminating Engineers
Designed for Industrial Service
Produced to meet Industrial Performance Standards
Stocked and Sold by Electrical or Industrial Supply Houses
CHAMPION Lamps

four good points...

Lamps bearing the Champion Diamond mark have these four points in their favor. Remember them whenever you buy Incandescent or Fluorescent Lamps for your plant.

FREE FILE ON ENGINEERED LAMP MAINTENANCE

tells you how to determine your most profitable cleaning cycle — how to eliminate 83% of your lamp burnouts — how to cut lamp replacement cost to a sixth of what it used to be. Let us mail you the complete file.

CHAMPION LAMP WORKS
Lynn, Massachusetts
A DIVISION OF CONSOLIDATED ELECTRIC LAMP CO

(Continued from page 33A)

NORTHERN CALIFORNIA SECTION

Associate Members:
Edgar, W. A., Jr., Chas. Von Bergen, San Francisco, Calif.
Hegler, B. F., U.S.N.R., c/o F.P.O., San Francisco, Calif.

OHIO VALLEY SECTION

Associate Member:
Blankemeyer, J. Paul, Optometrist, 2118 Beechmont Ave., Cincinnati, Ohio.
Student Member:
Herndon, W. F., University of Dayton, Dayton, Ohio.

OKLAHOMA CHAPTER

Associate Member:
DeCamp, James, Oklahoma Gas and Electric Co., Muskogee, Okla.

PHILADELPHIA SECTION

Associate Member:
Valentine, H. C., Garden City Plating and Mfg. Co., Upper Darby, Pa.

PITTSBURGH SECTION

Associate Members:
Butler, W. A., Pittsburgh Electric Supply Co., Pittsburgh, Pa.
McBride, T. G., Westinghouse Electric Supply Co., Pittsburgh, Pa.

PUGET SOUND SECTION

Associate Members:
Leach, P. C., Ketchikan Pulp Co., Bellingham, Wash.
Weigle, G. C., Seattle City Light, Seattle, Wash.

ROCKY MOUNTAIN SECTION

Associate Member:
Eby, D. H., Westinghouse Electric Corp., Denver, Colo.

ST. LOUIS SECTION

Member:
Simms, W. H., Union Electric Co. of Missouri, St. Louis, Mo.
Associate Members:
Cristofv, Cristjo, Shampaine Co., St. Louis, Mo.
Giesler, H. A., Citizens Electric Corp., Ste. Genevieve, Mo.
Hettich, O. H., Guarantee Electric Co., St. Louis, Mo.
Kramer, Louis, A.A.A. Electric Co., St. Louis, Mo.
Mueller, H. F., City of St. Louis, St. Louis, Mo.
Schneider, Max, Schneider Electric, St. Louis, Mo.
Welch, Wesley, Guarantee Electric Co., St. Louis, Mo.

SAN JACINTO SECTION

Member:
Little, Leonard, Worth Electric Supply Co., Houston, Texas.

SAN JOSE CHAPTER

Student Members:
Levin, R. E., Stanford University, Stanford, Calif.
Silver, Jack, Stanford University, Stanford, Calif.

SOUTHEAST FLORIDA CHAPTER

Associate Members:
Hughes, J. K., Triangle Electric Mfg. Co., Miami, Fla.
Magee, T. R., Westinghouse Electric Supply Co., Miami, Fla.
Phillips, A. V., III, R. L. O'Donovan Inc., Miami, Fla.
Wolcott, E. L., Westinghouse Electric Corp., Tampa, Fla.

SOUTHERN CALIFORNIA SECTION

Associate Members:
Beery, W. M., General Electric Co., Los Angeles, Calif.
Borland, R. B., Westinghouse Electric Corp., Los Angeles, Calif.
Crawford, F. W., C. W. Cole Co., Los Angeles, Calif.

Hart, P. G., Southern California Edison Co., Huntington Park, Calif.
Marvin, R. L., General Electric Co., Los Angeles, Calif.
McClintock, F. L., General Electric Co., Los Angeles, Calif.
McIllmoil, D. P., Westinghouse Electric Corp., Los Angeles, Calif.
Stamps, G. F., Westinghouse Electric Corp., Los Angeles, Calif.
Stockwell, H. H., Department of Water and Power, Los Angeles, Calif.
Sykes, J. V., Westinghouse Electric Corp., Los Angeles, Calif.

SOUTHWESTERN SECTION

Associate Member:
Milligan, M. W., Wright Light Inc., Dallas, Texas.

TORONTO SECTION

Member:
McRoberts, C. E., Amalgamated Electric Corp., Ltd., Toronto, Ont.

Associate Members:
Cameron, J. C., Ford Motor Co., of Canada, Ltd., Windsor, Ont.
France, W. L., Zenith Electric Supply, Toronto, Ont.
Kennedy, J. W., Amalgamated Electric Supply Corp., Ltd., Toronto, Ont.
Rubin, Bernard, Wiggs, Walford, Frost, and Lindsay, Toronto, Ont.
Wilkie, R. J., Hydro Electric Power Commission of Ontario, Toronto, Ont.

TWIN CITY SECTION

Associate Member:
Henn, E. F., Northern States Power Co., Minneapolis, Minn.

VANCOUVER ISLAND CHAPTER

Associate Member:
Beck, W. E., B. C. Electric Co., Ltd., Victoria, B. C.

POSITIONS AVAILABLE

The Engineering Research and Development Laboratories located at Fort Belvoir, Va. (20 miles south of Washington, D. C.) have openings for illuminating engineers in civil service grades GS5 through GS11. The laboratories are expanding their program in illumination which includes battle field illumination, search lights, fighting lights, light source research, vision research, traffic control equipment and construction lighting equipment. Applications should be sent to John A. Bartell, Chief, Illumination Section, or Oscar P. Cleaver, Chief, Mechanical and Electrical Engineering Dept., ERDL, Ft. Belvoir, Va.

SALES REPRESENTATIVES WANTED

The Modern Light Company of St. Louis is expanding its field sales force and agency sales contracts are available for the following territories: Illinois, Arkansas, Missouri, Indiana, Ohio, Wisconsin, Minnesota, Tennessee and Kansas. Representatives interested in an agency or commission basis are invited to communicate with The Modern Light Company of St. Louis, 7809 Maplewood Industrial Court, St. Louis 17, Mo.

REPRESENTATION WANTED

Manufacturer of widely used color matching lighting equipment and process instruments desires representation in the Pennsylvania-New Jersey area. Specialized lighting equipment used in textile mills, paper production, paint manufacture, canning, leather tanning and many other fields.

Contact Mr. W. B. Reese, Macbeth Corporation, P. O. Box 950, Newburgh, N. Y.

WANTED—
JUNIOR APPLICATION ENGINEER

Would you like to round out training in Lighting Engineering under one of the foremost engineers in the field?
The Chief Application Engineer of The Miller Company, Mr. G. W. Beals, has a position open as his assistant. The Miller Company being one of the oldest and one of the largest manufacturers in the lighting industry can offer a very bright future to the man qualifying. We desire a man, 24 to 30 years old, with a pleasing personality and a background of electrical and illuminating engineering. The work is fascinating, the pay is good and the training pointed toward a position as Field Sales Engineer.
Please write, stating your qualifications, to Mr. Beals' attention.

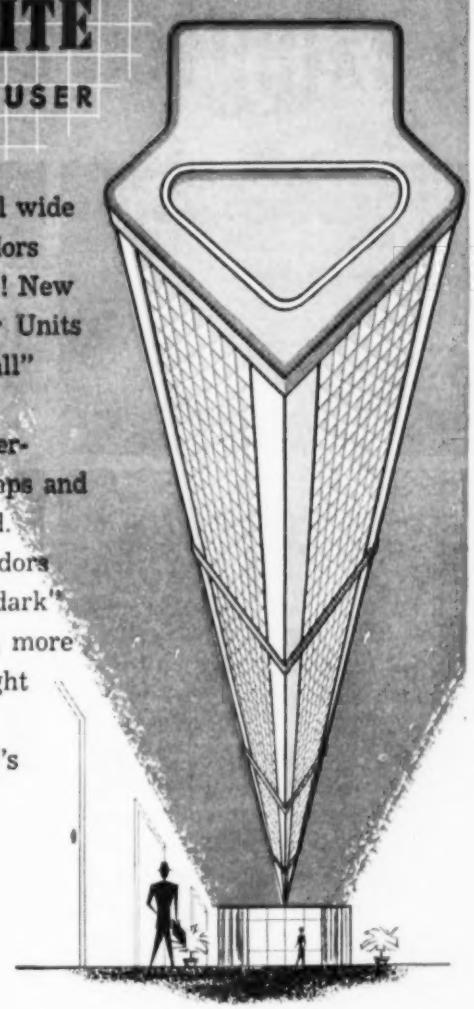
THE MILLER COMPANY
99 Center St. Meriden, Conn.

make hallways say, "Come in!"

new Guth V·C·U

"V" CORRIDOR UNIT

with GRATELITE* LOUVER-DIFFUSER



At last—you can fill wide hallways and corridors with practical light! New Guth "V" Corridor Units provide "wall-to-wall" illumination. The GRATELITE Louver-Diffuser shields lamps and is easily maintained. Hallways and corridors "come out of the dark" and turn into safer, more cheerful lines of light that guide the eyes and the step. V·C·U's available in 4′ & 8′, 1 & 2 light models.

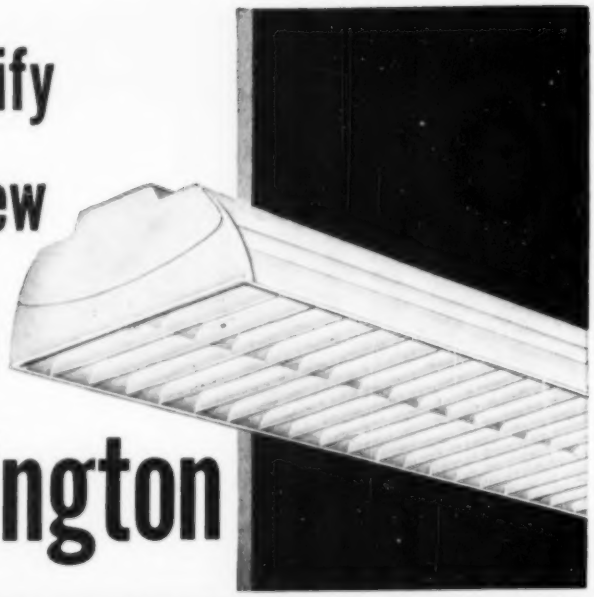
*Patents Pending
Trademark Registered

Write for complete information today.

Guth

THE EDWIN F. GUTH CO. ST. LOUIS 3, MO.

specify the new miller Lexington

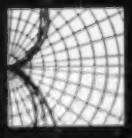


for correct school lighting

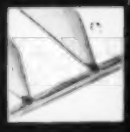
The new Miller LEXINGTON—a distinct advance in school lighting—gives you correct lighting of high efficiency and extremely low brightness—lighting that eliminates eye strain and improves physical well being of students. It provides it at L. O. C. (low overall cost)—through engineering features that make for easier, quicker installation, and materially reduce cost of maintenance, making it more economical over the years. You get more Value for your lighting dollars.

Write for Lexington and L. O. C. Folder

Miller has a complete line of Fluorescent, Mercury and Incandescent luminaires, covering a wide range of industrial and commercial lighting requirements. NATION-WIDE SERVICE is available through Miller field engineers and distributors.



High lighting efficiency—extremely low brightness



Extremely strong, rigid one-piece steel louver assembly

Engineered for easy lamping and servicing

Modern design—architecturally styled for interior harmony

THE miller COMPANY
SINCE 1844
meriden, conn.

INDEX TO ADVERTISERS
April 1953

Acme Electric Corp.	33A
Advance Transformer Co.	21A
Benjamin Electric Mfg. Co.	38A
Champion Lamp Works	34A
Corning Glass Works	37A
Curtis Lighting Inc.	4A
Day-Brite Lighting Inc.	20A
Garden City Plating & Mfg. Co.	14A
General Electric Co., Apparatus	10A-11A
General Electric Co., Lamp	22A
Edwin F. Guth Co.	35A
Jefferson Electric Co.	29A
Kopp Glass Inc.	18A
Lighting Products Inc.	17A
Litecontrol Corp.	23A
Miller Co.	36A
Mitchell Manufacturing Co.	19A
Pfaff & Kendall	30A
Pittsburgh Reflector Co.	32A
R.L.M. Standards Institute	Inside Back Cover
Radiant Lamp Corp.	33A
Rohm & Haas Co.	31A
Silvray Lighting Inc.	27A
Smithcraft Lighting Division	13A
Sola Electric Co.	24A
Southern Plastics Co.	28A
Sunbeam Lighting Co.	30A
F. W. Wakefield Brass Co.	Inside Front Cover
Westinghouse Electric Corp., Lamps	Back Cover
Westinghouse Electric Corp., Lighting	1A

Preston M. Geren
Joseph R. Pelich
W. G. Clarkson Co. } Associate Architects And Engineers

Yandell, Cowan & Love—Consulting Engineers

Empire Electric Co.—Electrical Contractor

Gruber Brothers, Inc.—Fixture Manufacturer

Surface mounted fluorescent luminaires in vice-president's office. Smooth opal glass ALBA-LITE side panels distribute light evenly throughout the room. Long lengths provide sleek, streamlined appearance.

Hinged FOTA-LITE glass bottom has louvers photographically reproduced through the entire thickness of the glass to assure accurate cutoff and low fixture brightness.

Adding architectural variety in the snack bar, are troffer units (48 in. long and 12 in. wide), using FOTA-LITE shielding glass. Smooth, flat surface of this nonwarping, nondiscoloring glass cleans with the wipe of a cloth.

How engineered glassware was used in lighting this windowless building

Here's an unusual lighting and design problem which shows the versatility you can get with engineered lighting glassware.

The Acme Brick Company general office building in Ft. Worth has no windows. Interior lighting gets no assist from natural daylight.

Yet, you can easily see how the architects, lighting engineers and fixture manufacturer have provided highly functional lighting and made a beautiful installation, too. They used a selection of CORNING FOTA-LITE and ALBA-LITE shielded fluorescent and incandescent luminaires.

Using these units in various design layouts affords high level, quality lighting for 22,800 sq. ft. of floor space. And the architectural flexibility of the glassware complements the design of the installation itself.

Give your customers *all* the benefits of high-efficiency lighting with low fixture brightness and modern styling by specifying CORNING engineered lighting glassware. The coupon will bring you full details of the many sizes and shapes available.

Front lobby also has FOTA-LITE in troffers and highly heat-resistant PYREX brand LENSLITES in recessed boxes for control of incandescent light sources.

Soft over-all lighting effect in hallways is obtained by using PYREX brand LENSLITES with wide-angle lens in recessed ceiling boxes.

CORNING GLASS WORKS

Corning, New York

Corning means research in Glass

CORNING GLASS WORKS, Dept.IE-4, **Corning, N.Y.**

Please send me:

☐ Booklet LS-32, describing Corning's full line of lighting ware.

☐ Photometric data sheets on ALBA-LITE, FOTA-LITE and PYREX brand LENSLITES

Name _____ Title _____

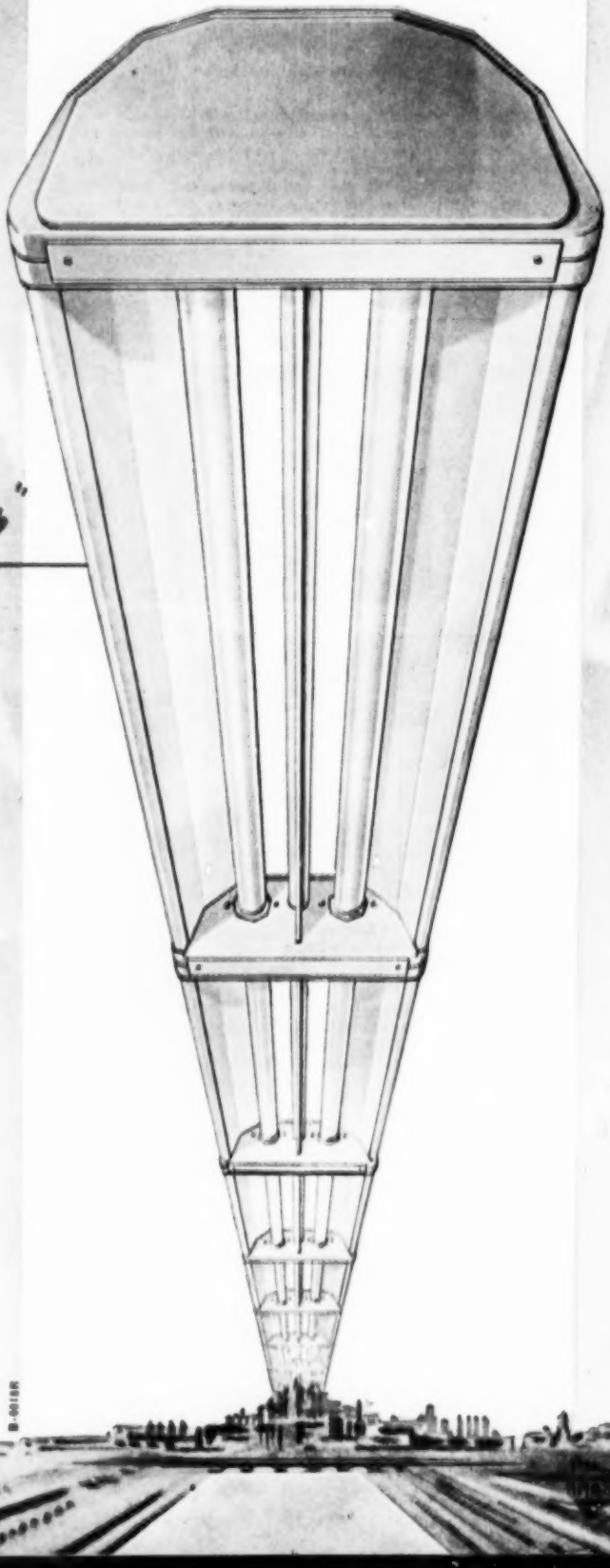
Firm _____

Address _____

City _____ Zone ____ State ____

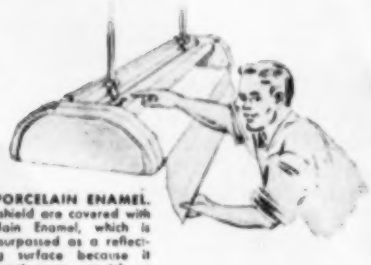
now, a new high in seeing comfort

through sensationally-increased UPWARD LIGHT...



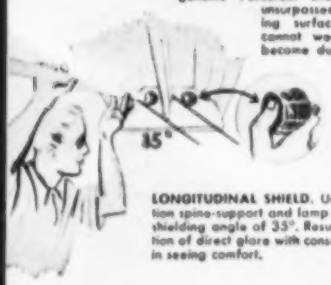
Now, approximately ¼ of light is directed UPWARD through a completely new, precedent-shattering concept of lighting unit design! The new Benjamin "Task-Master" is the modern solution to the brightness ratio problem. By combining greater upward flow of light with a new high of 35° in lamp shielding, "Task-Master" doubles, even triples, present standards for industrial seeing comfort. In addition to sensationally-increased UPWARD light and lamp shielding, "Task-Master" features revolutionary new, easier methods of installation and maintenance, such as those illustrated below. Send for FREE "Task-Master" Bulletin, giving further details. Write for Bulletin AD 5906. Benjamin Electric Mfg. Co., Dept. I, Des Plaines, Illinois.

BENJAMIN "Task Master"
Sold Exclusively through Electrical Distributors



DETACHABLE REFLECTORS are hinged to make possible easier, more thorough cleaning right on the fixture. They may also be detached and cleaned away from the unit. Available with sliding hangers, as shown.

"LIFE-TIME" PORCELAIN ENAMEL. Reflectors and shield are covered with genuine Porcelain Enamel, which is unsurpassed as a reflecting surface because it cannot wear, scratch or become dull.



"SPRINGLOX" LAMPHOLDERS are standard equipment. These rugged, all-metal, lifetime lampholders facilitate lamping and relamping through patented spring design.

LONGITUDINAL SHIELD. Unique combination spine-support and lamp shield provides shielding angle of 35°. Result: great reduction of direct glare with consequent increase in seeing comfort.

PRE-WIRED—NO WIRE SPLICING. Delivered with all connections made up to terminal block. Branch-circuit wire comes already run through spine support, entire length of unit.

SPECIAL "HOOK-UP" DESIGN makes it possible for the installer to temporarily hang one unit on another while connecting the jumper wires to opposite terminal blocks.

B-6018R

Gives the Industrial Lighting Equipment Buyer the answers to every question of Quality...

RLM
Questions & Answers
HOW RLM MANUFACTURERS WARRANTS CONFORMANCE TO RLM STANDARD SPECIFICATIONS
HOW THE RLM STANDARDS INSTITUTE DEVELOPS ITS SPECIFICATIONS
HOW THE RLM LABEL AIDS IN THE SPECIFICATION AND PURCHASE OF INDUSTRIAL LIGHTING EQUIPMENT

new Questions and Answers booklet explains why it pays to buy RLM-Labeled incandescent and fluorescent Lighting Units.

Electrical Contractor: "This RLM Booklet tells why I recommend RLM-labeled units."

This new, pocket-size RLM booklet is now being distributed by progressive contractors, architects, lighting engineers and others who recommend lighting for industry. They leave these booklets on the desks of their customers and prospects because they want to be sure the buyer understands that quality lighting equipment is *worth more* because it *costs less* in the long run.

This 8-page booklet answers the most frequently raised questions concerning quality incandescent and fluorescent lighting equipment and the RLM Label. It tells the buyer what he wants to know about the RLM Standards Institute, how the minimum standards of quality for construction and performance are established and how conformance to these standards is secured. Further it explains how the RLM Label provides assurance, not only of quality but of the uniformity of that quality in each and every individual lighting unit.

Included also is a list of the 26 illuminating engineering factors which are a part of every RLM standard specification. It is because of these factors that buyers obtain from lighting units bearing the RLM Label the assurance of better performance, long life, sustained lighting efficiency and economical operation.

Copies of the Booklet and 48-page Specifications Book available from any of the 28 manufacturers of RLM Lighting Units or by writing the RLM STANDARDS INSTITUTE, Suite 823, 326 W. Madison Street, Chicago 6, Ill.

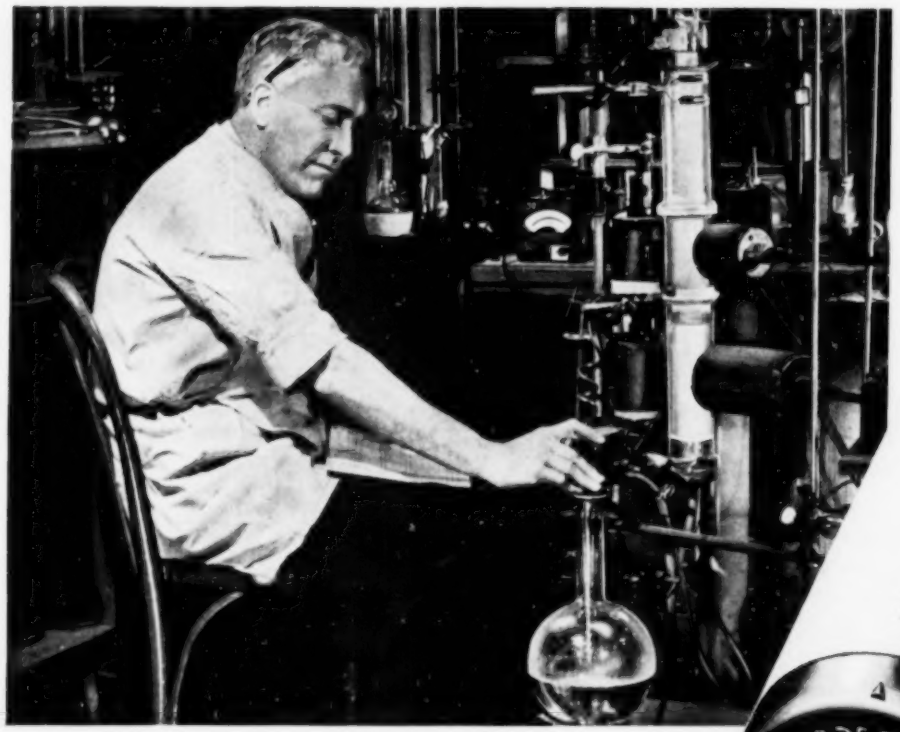
MANUFACTURER'S NAME
RLM
ELECTRICAL TESTING LABORATORIES, INC.

RLM STANDARDS INSTITUTE
A Certification

The letters RLM stand for Reflector and Lighting Equipment Manufacturers

R198

Rare gases up light and efficiency of new lamp



A Westinghouse Research Engineer is shown operating the rare gas apparatus in which the new krypton and argon gas fill were developed. As a result of krypton-argon, the new Westinghouse 90-watt fluorescent gives 6% more light for only 2% more current.

NEW WESTINGHOUSE 90-WATT FLUORESCENT LAMP

The light and efficiency booster in the new Westinghouse 90-watt fluorescent lamp is krypton-argon. This gas fill, exclusive with Westinghouse, takes only 2% more current to jump light output 6%. And after 7500 hours, this new lamp will still outshine every other lamp in its class.

The new 90-watt will fit present 85-watt fixtures. It will hold the level of light above your minimum foot candle value longer. It'll reduce annual cost of light. Contact your nearest Westinghouse Lamp Sales Office for more information.

YOU CAN BE SURE...IF IT'S

Westinghouse

See our three popular TV shows every week . . .

FREEDOM RINGS . . .
WESTINGHOUSE STUDIO ONE . . .
MEET BETTY FURNESS